MEASURING THE AURORA FROM HOME

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#154 MARCH 2018

The magnetic UNIVERSE

Take a closer look at the invisible magnetic forces shaping the cosmos

TESS: the hunt for new worlds

Why the number of exoplanet candidates is about to explode

NIGHT-BY-NIGHT GUIDE TO THIS MONTH'S SIGHTS

Mercury's evening appearance, the Moon occults the Hyades, and more

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This month's contributors include...

Michele Bannister
Planetary scientist

Michele relives last year's scramble to gather info on `Oumuamua, the first interstellar visitor to our Solar System. *Page 21*

Lucie Green
Solar astronomer

Lucie explains why we have Earth's magnetic field to thank for the aurorae and our very existence. *Page 32*

Govert Schilling
Science journalist

Let Govert introduce you to TESS, the new exoplanet-hunting satellite scheduled to launch this month. *Page 68*

Will Gater
Astronomy writer

Will tells the story of how astronomers joined forces to bring about multi-messenger astronomy's first success. *Page 38*

Welcome

The invisible force at work shaping our Universe

What do these things have in common: old TVs, loudspeakers and life on Earth? Answer: they all depend on magnetism. In our cover feature this month, Professor Lucie Green shows that it's not just on our home planet that this invisible force plays a decisive role. Right across the Universe, magnetic fields drive some of the cosmos's most dynamic processes. Turn to page 32 to find out more.

One of the most awe-inspiring effects of magnetic fields on Earth is the aurorae. But for many of us, the only way to see them is online. Not content with this, engineer Stuart Green built and installed his own magnetometer to record the solar wind's effect on his local magnetic field, giving him a constant record of auroral activity. Discover how he set up his equipment on page 44.

There's more practical astronomy on page 74, where Jamie Carter looks at the disappearance of a perennial observing favourite, Iridium flares. This year is the last chance to see and image these reflective satellites before the final one is deorbited to make way for a new non-flaring fleet. Make sure you catch one before they're gone!

Enjoy the issue.

Chris Bramley Editor

PS Our next issue goes on sale 22 March.

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Sky at Night Lots of ways to enjoy the night sky...

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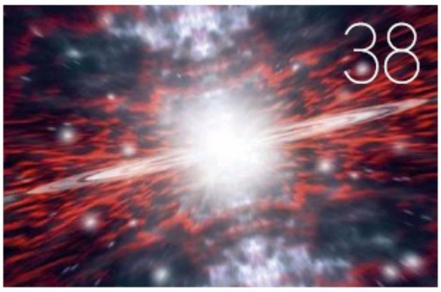
NEW TO ASTRONOMY?
Get started with The Guide on page 80 and our online glossary at www.skyatnightmagazine.com/dictionary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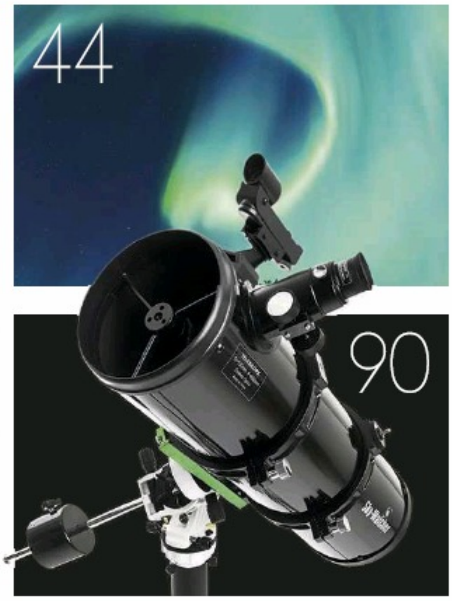
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MARCH'S BONUS CONTENT

THERE'S MORE ONLINE

HOW TO FIND IT

Visit **www.skyatnightmagazine.com/bonuscontent**, select March's bonus content from the list and enter the authorisation code **WWLVMAE** when prompted

March highlights

Watch *The Sky at Night*

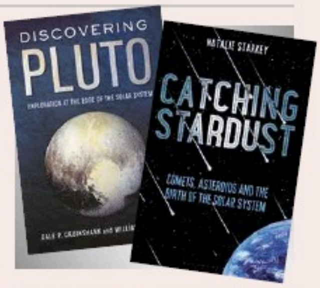
The team explore the astounding revelation that most of the Universe is invisible. Maggie finds out about the unknown substance called 'dark matter', and Chris goes underground to visit a facility that is searching for it. Jim Al-Khalili reveals how colliding stars help astronomers investigate the force that seems to be accelerating the expansion of the Universe.

Dr George Ricker: the launch of TESS

The mission's principal investigator reveals how the satellite will hunt for worlds beyond the Solar System.

Build a rotating meteor shutter

Access extra PDF guides, images and diagrams to help with this month's DIY *How To* guide (page 82).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EXPLORATION AT THE EDGE OF THE SOLAR SYSTEM
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NATALIE STARKEY
CATCHING STARDUST
COMETS, ASTEROIDS AND THE BIRTH OF THE SOLAR SYSTEM

Get sneak previews of books we've reviewed

Download an audio and PDF excerpt from two of the books reviewed in this month's issue (page 102).

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- ▷ **Eye on the sky**
- ▷ **Extra EQMOD files**
- ▷ **Binocular tour**
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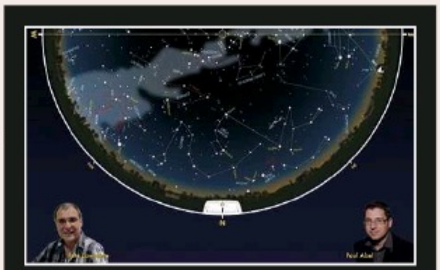

EVERY MONTH
Virtual Planetarium

With Paul Abel and Pete Lawrence

Explore March's night-sky highlights with Paul and Pete.

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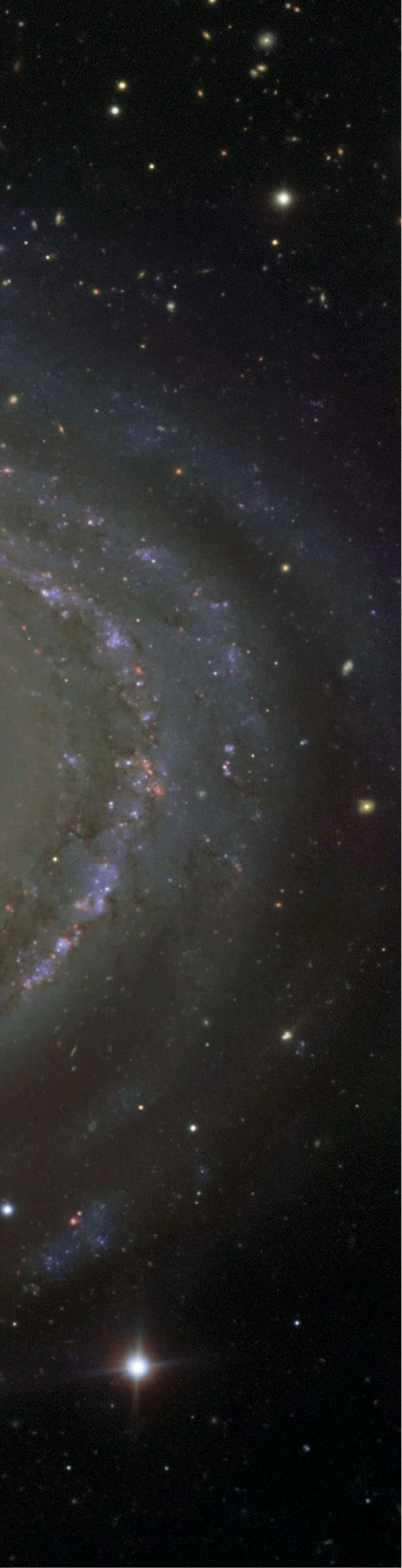


ESO

Raising the bar

Light from the early Universe reveals that barred spiral galaxies, like our own Milky Way, are more common today than they once were

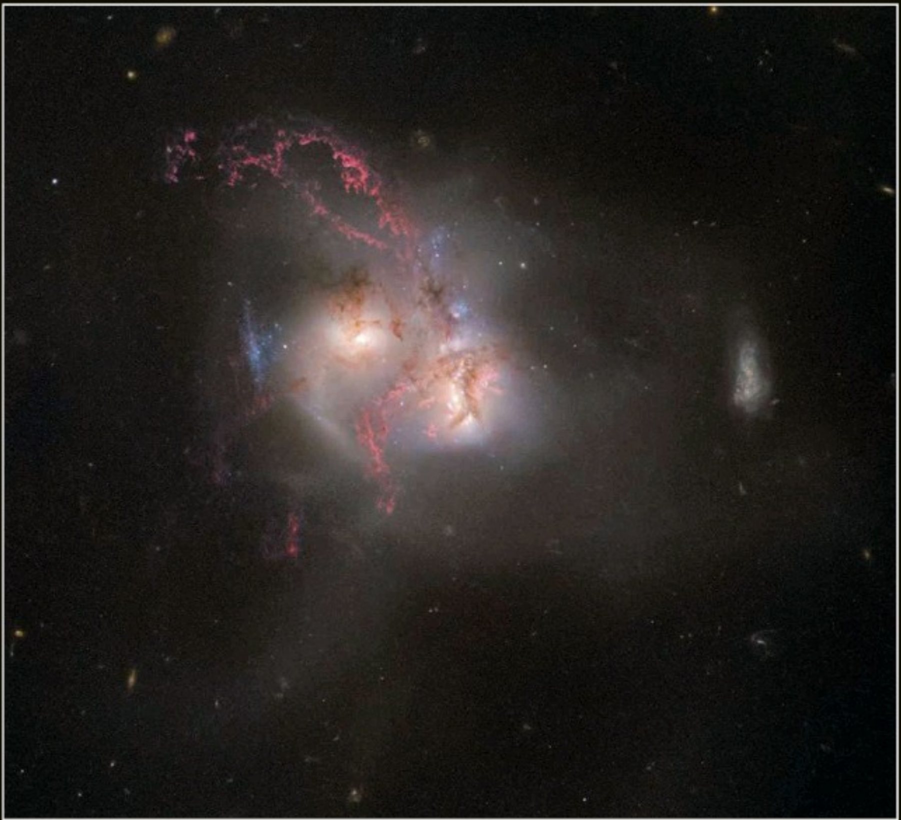
VERY LARGE TELESCOPE, 1 JANUARY 2018

In this image taken by the Very Large Telescope, the galaxy NGC 1398 sits face-on to us, revealing its intricate structure perfectly. Dark lanes of cosmic dust within its spiral arms feed the pink star-forming regions dotted throughout, and at the heart of the galaxy lies a huge bar of stars. NGC 1398 is a perfect example of a barred spiral galaxy, so-called because its spiralling arms originate not from the centre, as with other spiral galaxies, but from this bar-like structure. It's thought that most spiral galaxies in today's Universe are barred, but this wasn't always the case. A 2008 study using the Hubble Space Telescope revealed that seven billion years ago, barred spiral galaxies were less common. Since then the proportion has more than tripled: while just 20 per cent of spiral galaxies had bars in the early Universe, that figure is approaching 70 per cent today.

There is still no definitive answer as to why so many spiral galaxies form this distinctive linear structure. It's thought that the bar forms as a result of the stars in the galaxy's inner region developing an elliptical orbit: as the stars deviate from their circular path, their elliptical orbits become more pronounced, leading to the formation of a bar. The drive behind this elliptical orbit is not yet known.

What's becoming clear, however, is that bars can be important features in driving the evolution of their host galaxies. They force cosmic gas towards the galactic centre, fueling star formation, creating central bulges of stars and feeding supermassive black holes.

Observations of the Milky Way have revealed a central bar-like bulge, leading astronomers to conclude that our own Galaxy is a barred spiral. While we can't yet view the Milky Way from afar, observing barred spirals such as NGC 1398 is the next best thing and doing so can help us understand the structure and evolution of our place in the Universe.



▲ Galactic dance

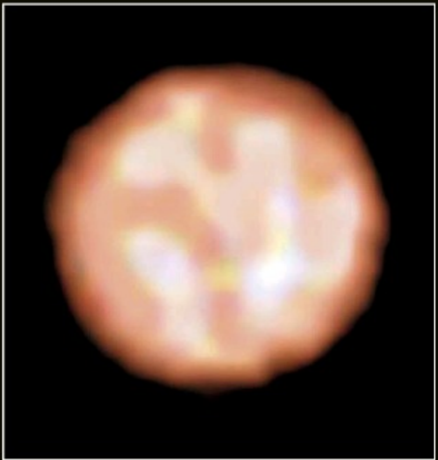
HUBBLE SPACE TELESCOPE, 14 DECEMBER 2017

NGC 5256 is made up of two galaxies that are merging, creating a collision that causes gas and dust to be whirled about and flung into space. The nuclei of the two galaxies are just 13,000 lightyears apart and the energy from their collision is enough to generate the birth of new stars. Yet despite the destructive nature of mergers such as these, individual stars within the two galaxies rarely collide due to the vastness of the distances between them.

▼ Stellar close-up

VERY LARGE TELESCOPE, 20 DECEMBER 2017

For the first time, astronomers have been able to directly observe granulation patterns on the surface of a star outside our Solar System. The star is Pi1 Gruis, a red giant with a mass the same as the Sun, but a diameter 350 times larger. Each of its convective cells, or granules, is about 120 million kilometres across; just one granule would stretch from the Sun to beyond Venus.



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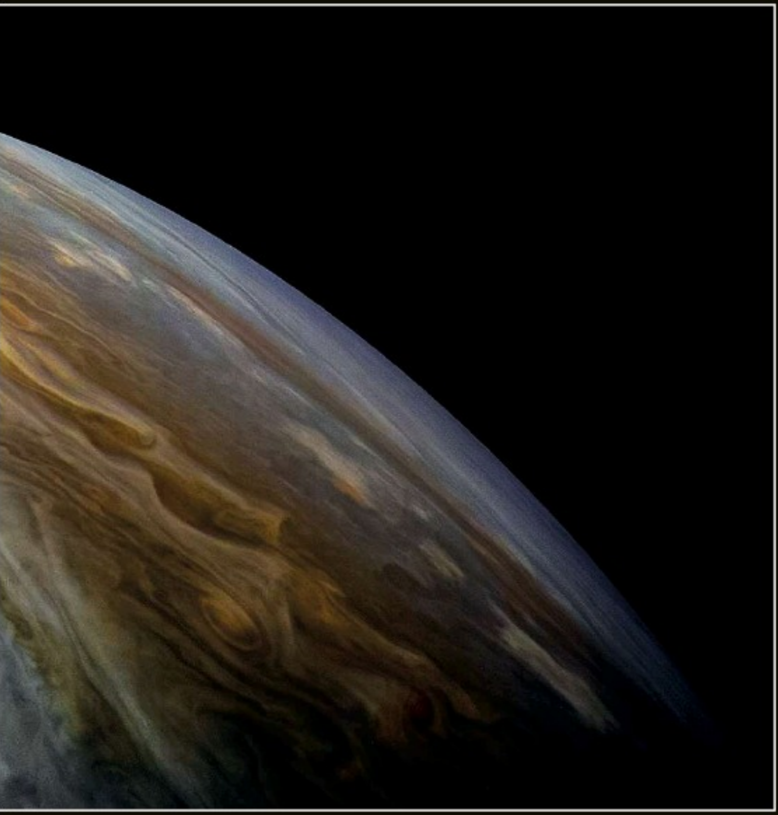

◀ Above the clouds

JUNO SPACECRAFT, 16 DECEMBER 2017

NASA's Juno spacecraft captured this view of Jupiter from a distance of 13,604km above the cloud tops during its 10th close flyby of the planet. It shows swirling cloud in Jupiter's southern hemisphere, including the South Temperate Belt, which is the dark section on the far left intersected by white clouds. This image was processed by citizen scientist Kevin M Gill using raw data captured by the spacecraft.

YOUR BONUS CONTENT

A gallery of these and more stunning space images

▼ Relics of the early Universe

ESO/MPG 2.2M TELESCOPE, 17 JANUARY 2018

Globular clusters are some of the oldest known objects in the Universe and can contain millions of stars. They're thought to have formed out of collapsed clouds of gas and dust around the same time the Milky Way formed, shortly after the Big Bang. This particular specimen, NGC 3201, is located about 16,000 lightyears away.

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Bulletin

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Our experts examine the hottest new astronomy research papers

Neutron stars could cause FAST RADIO BURSTS

The radio waves from eruptions are highly twisted, suggesting a strong magnetic field

The cause of intense flashes of radio emissions known as fast radio bursts (FRBs) could soon be revealed. A team of researchers, including some from the Breakthrough Listen project searching for signs of alien life, have recently found that radio signals from FRB 121102 probably passed through an intense magnetic field, such as those found around neutron stars.

FRB 121102 is unusual in that it has been seen bursting over 200 times, whereas all other FRBs have only burst once. This has allowed researchers to study the bursts and find that the emissions from FRB 121102 are not only highly polarised but that the polarisation is twisted, an effect usually caused by an exceptionally strong magnetic field. As neutron stars are known to have strong magnetic fields, the discovery lends weight to the idea that these objects create FRBs. How they do this, however, is still up for debate.

"With these observations we hope to distinguish between the two competing hypotheses of a neutron star either near a black hole or embedded in a powerful nebula," points out Jason Hessels from the University of Amsterdam.

FRBs release as much energy in a millisecond as the Sun releases over the course of an entire day. Since they were first spotted in 2007 several possible causes for FRBs have been suggested, ranging from neutron stars to highly advanced alien civilisations.

"There are still many questions, such as how can a rotating neutron star produce the high amount of energy typical of an FRB? We can't completely rule out the ET hypothesis for FRBs in general," says Vishal Gajjar of Breakthrough Listen and the Berkeley SETI Research Center.

▸ **See Comment, right**

The complicated, multi-peak structure of FRB 121102 could have been caused either during the signal's creation or during transit

IMAGE DESIGN: DANIELLE FUTSELAAR · PHOTO USAGE: SHUTTERSTOCK.COM

COMMENT

by Chris Lintott

I first heard about this result from the press and instead of being intrigued it made me want to throw things! Not because the result isn't fascinating but because of how the news was reported.

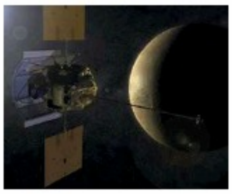
The new measurements are highly significant. In addition to measuring the magnetic fields, they also show that the source is coming from a star-forming region, displaced from the centre of the dwarf galaxy that hosts it. That clue is priceless in hunting for the cause of these things.

Yet, because of the involvement of astronomers from SETI, the story all too easily gets reduced to a disappointing search for aliens. Instead of thinking about the excitement of this detective work, we become disappointed alien hunters.

Don't get me wrong, SETI is an important project with real scientific value. But not everything interesting in the Universe has to be aliens. Here they'd be best left out of it.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF



SOLAR WEIGHT LOSS SLOWS

A study of Mercury's orbit has allowed researchers to measure the mass loss of the Sun more precisely than ever before. During its lifetime, the Sun is expected to lose 0.1 per cent of its mass, weakening its gravitational hold over the planets and allowing their orbits to grow. Astronomers used data gathered by NASA's Messenger probe to determine how much mass the Sun has lost. The data showed that the Sun is shedding slightly less mass than expected.

ISS USES PULSAR GPS

The International Space Station has tracked its position using pulsars for the first time. Astronomers measured the tiny changes in pulses emitted by pulsars to plot the ISS's position to within 5km. The method could allow future spacecraft to navigate without direct contact with Earth. "It's a great way to apply some of our astrophysics to exploration goals that include going to the outer Solar System and beyond," says Keith Gendreau from Goddard Space Flight Centre.

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The gravity and stellar winds of massive stars have a huge 'feedback' effect on the space around them

The galaxy is full of HEAVYWEIGHTS

An excess of massive stars could change our view of the Milky Way

A new study of heavyweight stars has shown that our Galaxy has an excess of high-mass stellar objects, forcing researchers to rethink their assumptions about the Milky Way's composition. It could also affect the number of gravitational waves that astronomers expect to be able to see.

The team behind the study examined the star-forming region 30 Doradus using ESO's Very Large Telescope. They observed over 1,000 massive stars, 250 of which were found to have masses 15-200 times that of the Sun – many more high-mass stars than had been expected.

The team was aiming to measure the initial mass function (IMF) – a measure of the distribution of masses within a particular stellar population. But in most places in the Galaxy high-mass stars are relatively rare, so measuring their precise number is difficult; stars over 10 solar masses make up just one per cent of the stellar population.

To find enough massive stars to undertake a study, the team looked toward 30 Doradus, a large, local star-forming region. After studying the region, the researchers found that its IMF was much more weighted to the massive end than previously thought. The finding could have implications for our understanding of how the radiation and strong stellar winds produced by these massive stars affect their surroundings – a process known as feedback – and also for how these giants end their lives in supernovae, seeding the Universe with the heavy elements needed to form planets.

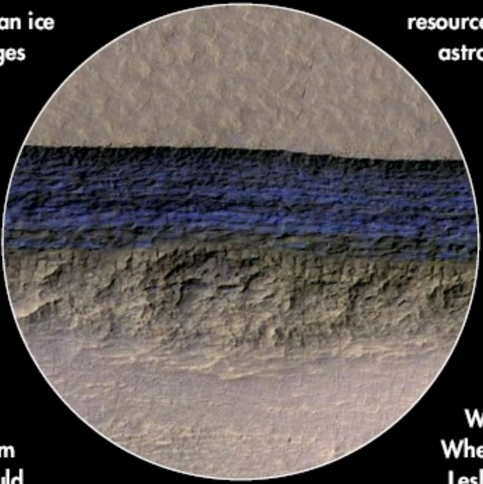
"To quantitatively understand all these feedback mechanisms, and the role that massive stars play in the Universe, we need to know how many of these behemoths are born," says Phillipp Podsiadlowski, from the University of Oxford.

"The finding could change our view of the cosmos, as more large stars mean more supernovae, potentially altering the chemical balance of the Universe," says the study's lead author Fabian Schneider also from the University of Oxford.

"Also, the formation rate of black holes might be increased by 180 per cent, directly translating into a corresponding increase of binary black hole mergers that have recently been detected via their gravitational wave signals."
www.eso.org

Ice on the Martian slopes

The deposits could be an excellent spot for a future Mars mission



▲ Underground ice, highlighted in blue, on Mars has been exposed by landslides

Eight thick deposits of Martian ice have been identified in images taken by NASA's Mars Reconnaissance Orbiter (MRO). The ice was probably laid down as snow a very long time ago but has recently been uncovered by the weathering of steep slopes, known as scarps, found in both the northern and southern hemispheres of Mars.

The ice is as much as 100m thick in some places and could be useful for future missions to the Martian surface as a resource, a water supply for astronauts and a research tool.

"If you had a mission at one of these sites, sampling the layers going down the scarp, you could get a detailed climate history of Mars. It's part of the whole story of what happens to water on Mars over time, [and may answer questions such as] where does it go? When does ice accumulate? When does it recede?" says Leslie Tamppari, the MRO's Deputy Project Scientist.

mars.nasa.gov/mro

Star clusters hide black holes

The first stellar mass black hole has been detected in a globular cluster. The black hole is inactive, so would have remained hidden if not for the strange behaviour of a nearby star.

Every 167 days, one of the stars in NGC 3201 is flung backwards and forwards at several hundred thousand kilometres per hour.

"It was orbiting something that was completely invisible, which had a mass more than four times the Sun – this could only be a black hole! The first one found in a globular cluster by directly observing its gravitational pull," says Benjamin Giesers from the Georg-August Universität Göttingen, who led the study.

As globular clusters are home to many massive stars, which can create stellar-mass black holes during their death throes, it has long been suggested that many black holes could be hiding in such environments. "This finding helps in understanding the formation of globular clusters and the evolution of black holes and binary systems – vital in the context of understanding gravitational wave sources," says Giesers.

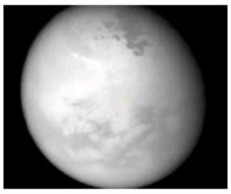
www.uni-goettingen.de/en/1.html

An artist's impression of how the star and its invisible black hole companion appear in globular cluster NGC 3201

NEWS IN BRIEF

UK SCIENTISTS HONOURED

Helen Sharman (above), Britain's first astronaut, has been recognised in the New Year's honours list. Also listed was astrophysicist Michele Dougherty, who built magnetometers for both the Cassini and JUICE spacecraft. "I'd like to congratulate Helen and Michele on behalf of everyone at the UK Space Agency. They've made huge contributions to the space community and inspired thousands of young people," said Graham Turnock, Chief Executive of the UK Space Agency.

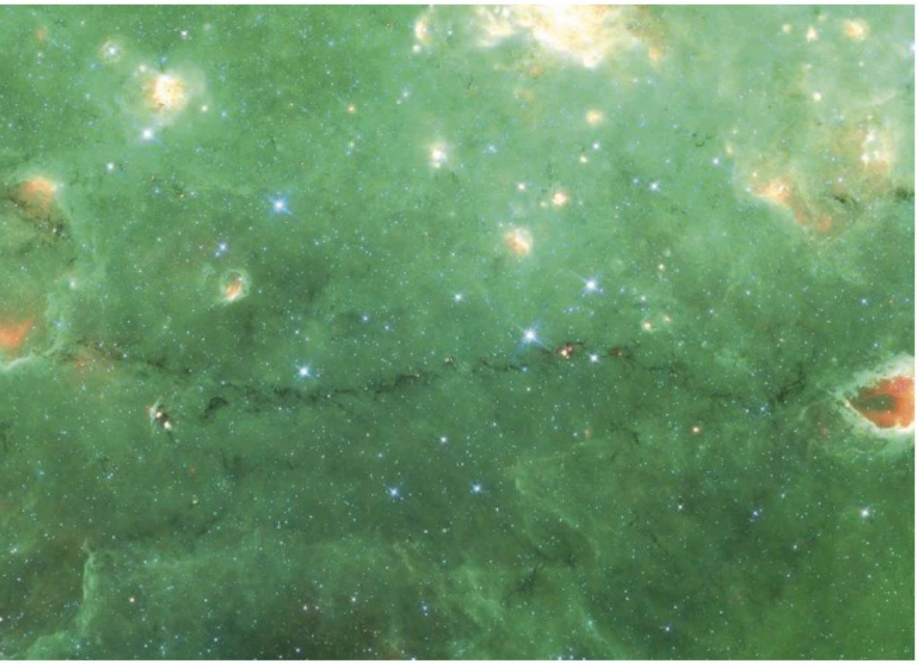


TITAN FULLY MAPPED

A new map of Titan has been created using data collected by the Cassini spacecraft. The map reveals several previously unnoticed mountains under 700m in height, as well as two equatorial depressions that could be dried seas or cryovolcanic flows. The map also shows Titan's seas all have the same elevation, just as Earth's oceans do, suggesting that all the liquid bodies on Titan are connected somehow, either by channels or through a subsurface flow.

Catching the Milky Way's monsters

A new study has corralled and begun to classify the giant gas filaments that help form our Galaxy



▲ **Nicknamed 'Nessie', this 300-lightyear-long dark filament of gas could be part of the Milky Way's skeleton**

NASA/JPL/SSC

A brave trio of astronomers based at Harvard's Centre for Astrophysics have been monster hunting in the Milky Way. Their first discovery was 'Nessie'; not a creature from the depths of a Scottish loch, but rather a long, dark filament slashed through our Galaxy's disc. The structure, made up of a long thread of relatively dense gas whose sinuous turns reflect those of the monster 'seen' in the classic photo, is hundreds of lightyears long.

When I first heard about it, I thought the existence of such a structure was just a curiosity, but this 'Nessie' is a complicated beast. Understanding how such a filament could have formed, and how it has resisted being ripped apart by the turbulent structure of the Galaxy's gas clouds, is not easy. A proper survey is needed and others have set out on this quest before. Six separate papers have tried to compile catalogues of giant filaments, using data from infrared and radio surveys within which dense clumps of gas stand out. Some inspected their data by eye while others used algorithms and machine learning to look for long filaments, so the first task for Catherine Zucker – the PhD student leading this monster hunt – was to bring these different datasets together in a useful way, using data from ESA's Herschel observatory to measure their properties.

The results of her and her team's hard work are fascinating. There are, it turns out, several types of monsters lurking in the Milky Way. While all share a habitat – closer to the centre of the Galaxy than we are, and close to the middle of the disc – there are distinct differences. The most obvious bear similarities to how we imagine the Loch Ness Monster to look: they're long, thin filaments that, thanks to a significant fraction of dense gas, appear capable of forming massive stars (in some, three quarters of their gas is dense enough to be able to form stars). Such large and thin features are almost certainly the result of gravity working on a grand scale. What's more, these giant filaments may be very important, acting like bones to underpin the whole spiral structure of the Milky Way.

> "The three types of filaments seem to tell different stories about how gas collapses locally and how the Milky Way is put together"

The second type, which have less dense gas and a more rounded appearance, may be squeezed versions of normal molecular clouds, which form the bulk of the Milky Way's star-formation regions. A comparison with recent simulations suggests that this idea is at least plausible, though more work – probably with more powerful computers – is needed. The third and final type sits between the previous two; these are as thin as the 'Nessie' filament but contain relatively little dense gas. They seem to be networks of molecular clouds, sorted into a regular pattern by gas collapsing in a particular way, specifically due to something called a 'sausage instability' (a wonderful technical term).

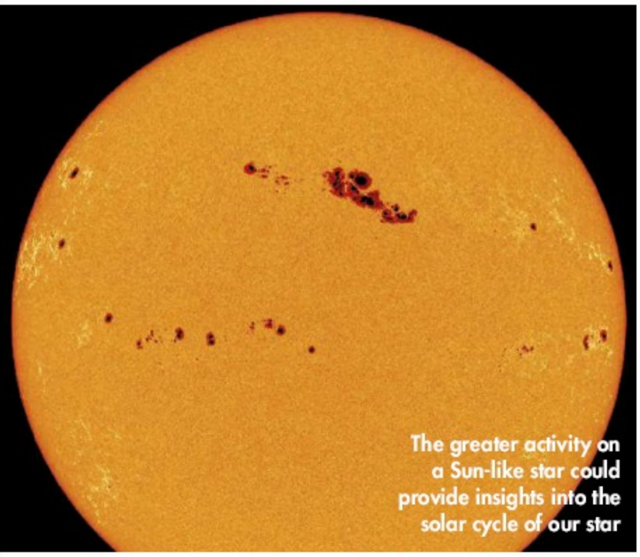
The three types of filaments seem to tell different stories about how gas collapses locally and how the large-scale structure of the Milky Way is put together. In corralling all of these beasts in the same place, Zucker and her team have done a great service to those who'll follow and continue our exploration of the Milky Way's wild places.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

CHRIS LINTOTT was reading… *The physical properties of large-scale galactic filaments* by Catherine Zucker, Cara Battersby, Alyssa Goodman
Read it online at arxiv.org/abs/1712.09655

Star to unlock Sun's secrets

Its stellar cycle could be the key to understanding the Sun's activity



The greater activity on a Sun-like star could provide insights into the solar cycle of our star

A new study of a Sun-like star could give researchers an insight into the solar cycle, the poorly understood 11-year period during which the surface of our Sun alternates between high and low activity.

The key could lie with a star 120 lightyears away in Cygnus, which is a similar mass, size and age to our Sun, but is much richer in elements heavier than helium. Observations dating back to 1978 have shown the star has its own cycle, lasing 7.4 years and with double the variation in activity of the Sun. The heavy elements are thought to be responsible for the difference.

By studying the star further, researchers hope to better understand the motions of material and magnetic fields within stellar interiors that drive this cycle. Predicting the solar cycle is important as it can have an effect on Earth's climate.

www.au.dk/en

Astronaut John Young passes away

The ninth man to walk on the Moon, John Young, passed away on 5 January, aged 87. Young was NASA's longest serving astronaut, staying with the agency for 42 years, spending 835 hours in space across six separate flights before retiring in 2004.

He was one of the pioneers of human spaceflight, and took part in many of the agency's greatest moments starting with the first crewed Gemini flight in March 1965. Young was on the crew of Apollo 10, which flew in May 1969 and served as the commander of the Apollo 16 mission in April 1972, during which he drove the Lunar Rover on the Moon's surface. He later commanded the maiden voyage of the Space Shuttle programme, ushering in a new era of spaceflight.

www.nasa.gov

▲ John Young, who flew into space six times, passed away in January after suffering with pneumonia

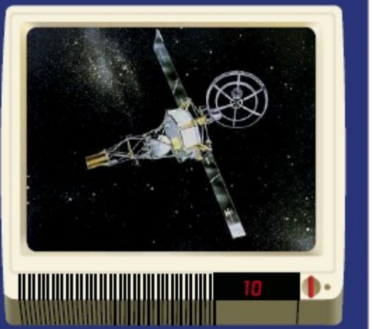
LOOKING BACK THE SKY AT NIGHT

20 March 1963

In the episode of *The Sky at Night* broadcast on 20 March 1963, Patrick Moore discussed Mariner 2, which had recently performed the first ever flyby of another planet.

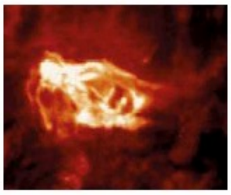
Though both the Soviet Union and NASA had sent previous missions to Venus, Mariner 2 was the first to succeed when it flew past the planet on 14 December 1962. Not much was known about Venus beforehand, as its thick clouds hid the surface from view. It was thought the world, which is similar in size to Earth, might hide verdant rainforests, but Mariner 2 quickly obliterated this notion when it found average surface temperatures were around 500°C – hot enough to melt lead.

Mariner 2 also examined the planet's magnetosphere and some of its interactions with the solar wind, but it would be the Soviet Venera programme, which sent 16 missions to Venus, that would really give our first window through the clouds to view our closest planetary neighbour.



▲ Mariner 2's flyby of Venus was the hot topic in March 1963

NEWS IN BRIEF



SPRINGTIME ON THE SUN

A particle eruption on the far side of the Sun that hurled out unusually high levels of helium-3 and iron was recently uncovered in archive data from the twin STEREO solar orbiters. The eruption was followed by ultraviolet radiation moving in a spiral, suggesting the solar plasma was twisting around the Sun's magnetic field lines. These field lines can suddenly release their energy like a spring and could have selectively flung these particles into space.

NO ALIENS AT TABBY'S STAR

The star that made headlines in September 2015 as the potential site of an alien megastructure doesn't appear to be surrounded by extraterrestrial technology. In a bid to explain its sporadic dimming and brightening, over 1,700 people helped fund a study of Tabby's star, as it's now known, using the Las Cumbres Observatory. Data from the study shows that whatever is blocking the light is more likely to be dust rather than alien technology.

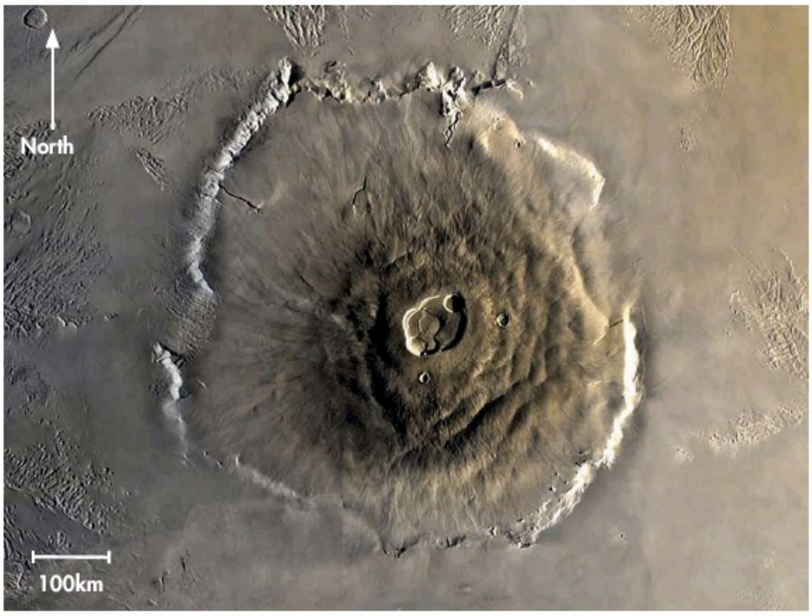
SOHO (ESA & NASA), NASA X 2, NASA/MPS, NASA/SOFIA/LYNETTE COOK

CUTTING EDGE

Our experts examine the hottest new research

Olympus Mons may once have been an island

An ancient landslide at the giant volcano may have been carried away by an encircling ocean



▲ **The spread of landslide deposits around Mars's biggest volcano suggests they may have been distributed by an ocean**

NASA/JPL

Olympus Mons on Mars is the tallest volcano in the entire solar system. Its summit towers 25km above its base, which is around 620km in diameter. But it's not just the sheer size that is notable about this mountain. Unlike any other Martian volcano, the slope of Olympus Mons doesn't smoothly merge with the surrounding ground, but is cut off around the circumference with a steep cliff face. The geological term for this is a 'basal scarp'. It's clearest along the northern and western flanks of the mountain, but has been partially or completely obscured around the rest of the volcano's perimeter by later lava flows.

Spreading out from the edge of the steep basal scarp are 10 or so huge oval-shaped, rough deposits known as aureoles. Various theories have been proposed since the 1970s as to what created these aureoles, from lava flows to volcanic deposits emplaced beneath glaciers. But the consensus today is that their shape is best explained by catastrophic landslides – rubble that spilled out across the surrounding landscape from landslides off the flank of the mountain around 3.5 billion years ago.

Fabio Vittorio De Blasio in the Department of Earth and Environmental Sciences at the University of Milan has been studying the basal scarp and surrounding aureole deposits at Olympus Mons. By using the very accurate topological maps that we now have of the Martian surface, De Blasio was able to calculate the total amount of material making up the aureole deposits. From this he could reconstruct what the original outline of Olympus Mons might have looked like, before its flanks collapsed in these colossal avalanches of rock.

He estimates that the initial shape of Olympus Mons would have been 200km wider in the western and north-western directions before the collapse of the aureole landslides. What's really strange about the northern and western aureole deposits, though, is just how far they have spread across the surface – over 700km from the scarp. That's an extremely long way for rocky boulders to roll along the ground. What De Blasio argues is that, in fact, these particular landslides fell into an early ocean on Mars and the debris was carried further along the seafloor in the powerful turbidity current created in the water, just as happens in Earth's deep-sea with underwater landslides. Indeed, when De Blasio looked in detail at a ridge located at the end of the northern aureole he found a sedimentation pattern that looks very much like a tsunami deposit.

> "This all adds support to the idea that ancient Mars once hosted a great ocean in its northern hemisphere basin"

This all adds further support to the idea that ancient Mars once hosted a great ocean in its northern hemisphere basin. And for me, the striking mental image is of a youthful Olympus Mons, not towering over dusty plains today, but as a volcanic island, its gentle flanks forming a shoreline lapped by waves. De Blasio points out that the volcanoes on Earth with a profile most similar to that of Olympus Mons are those of the Canary Islands and Hawaii. These volcanoes have experienced landslides into the ocean, and have steep cliffs like the basal scarp of Olympus Mons. Not only that, but the surrounding seafloor is also covered with far-spreading deposits similar to the Martian aureoles.

LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *The pristine shape of Olympus Mons on Mars and the subaqueous origin of its aureole deposits* by Fabio Vittorio De Blasio
Read it online at www.sciencedirect.com/science/article/pii/S0019103516304110

DESTINATION: HOUSTON

IF YOU'RE A LOVER OF ALL THINGS SPACE, OR WANT TO TREAT SOMEONE SPECIAL WHO IS, HOUSTON SHOULD BE TOP OF YOUR LIST WHEN VISITING THE U.S.

Deep in the heart of Texas, Houston is a cosmopolitan city with something for everyone. A plethora of parks, museums, restaurants and classy bars awaits you, all underpinned by that famous southern hospitality. And for those who eat, sleep and breathe space, there is one attraction that you definitely cannot miss: Space Center Houston, where some of the most famous space missions in history were planned, controlled and trained for.

Situated next to NASA's Johnson Space Center, this museum's exhibits include the iconic mission control from the dramatic Apollo 13 mission, of "Houston, we have a problem" fame. It also offers a wide range of interactive equipment, including machines that let you try picking up an object in space, land a spacecraft and experience 3G in a gyroscope. For a truly immersive experience, book ahead for a Level 9 Tour, which grants you an in-depth look behind the scenes at NASA.

And when you're all spaced out, why not take a relaxing stroll in either Buffalo Bayou or Hermann Park in the afternoon sun? Or if you're looking for something else to occupy the mind, try the Houston Museum of Natural Science, or the Museum of Fine Art, Houston. Then in the evening, step out to the historic Downtown to sample some of the city's best bars, before tucking in to your choice of a diverse range of cuisine, from Mexican to Vietnamese. Sometimes though, the only thing that will fit the bill is a good old Texan steak.

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A NEW HORIZON

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What's on

Our pick of the best events from around the UK

Celebrate 50 years of South West Herts Astronomy in Cassiobury Park

PICK OF THE MONTH

Stargazing in the Park

Cassiobury Hub, Cassiobury Park, Watford, 17, 18 and 24 March, 7.30pm

South West Herts Astronomical Society is marking its 50th anniversary this year with a series of public events celebrating humanity's fascination with the cosmos and desire to look up at the night sky.

Join the society for three stargazing evenings, each being held at the newly opened hub in Cassiobury Park. Society members will be on hand with their telescopes giving visitors the opportunity to observe the night sky under the tutelage of seasoned astronomers. Newcomers are welcome to these guided sessions.

Cassiobury Hub will host an indoor astrophotography exhibition at the same time, marking 50 years of astronomy images and showcasing some of the best astrophotos captured by society members. Attendees can also have their photo taken with a UK Space Agency space suit, as well as view lunar rock samples brought back to Earth by Apollo astronauts.

The event will include children's activity packs provided by the UK Space Agency and the Science and Technology Facilities Council.

All the events are free and open to everyone, and refreshments will also be available. For more information about South West Herts Astronomical Society and to see a list of its upcoming public meetings and talks, visit the society's website.

www.swhas.org

BEHIND THE SCENES

The Sky at Night returns in April

The Sky at Night is taking a break this month and will return in April with more adventures in astronomy and spaceflight. In the meantime you can view past episodes and clips from the show, including a selection of archive programmes featuring Sir Patrick Moore, on the BBC Four website. The site also includes astrophotography galleries and practical astronomy guides that will help you navigate the night sky. Visit **www.bbc.co.uk/programmes/b006mk7h.**

SIMON JACOBS, ESA/ATG MEDIALAB/BACKGROUND: ESO/S. BRUNIER, CERN, BBC

The Gaia Mission

Room 6.41, Royal College Building, University of Strathclyde, Glasgow, 15 March, 7.30pm

Gaia is a European Space Agency mission to create a 3D map of the Milky Way. This incredible project is being undertaken by the Gaia spacecraft, which is currently in orbit around the Sun. Dr Nicholas Rowell of the University of Edinburgh leads this talk for the Astronomical Society of Glasgow, discussing what we've learned so far and what Gaia may yet reveal. Admission is free.

theasg.org.uk

Peake's Pod

Museum of Science and Industry, Manchester, 10 March–13 May

See the Soyuz TMA-19M capsule that brought UK astronaut Tim Peake safely back to Earth in 2016, when it arrives at Manchester's Museum of Science and Industry as part of a free, temporary exhibition. Also, for £6 budding astronauts aged 13 and over can experience a virtual reality mission inside a Soyuz capsule narrated by Tim Peake.

www.msimanchester.org.uk/whats-on

The Large Hadron Collider

Queen's Buildings, Cardiff University, 15 March, 7.30pm

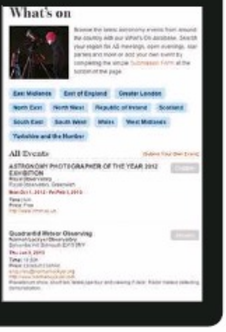
Over 10,000 scientists and more than 100 countries are involved in the operation of Large Hadron Collider (LHC) at CERN, exploring different theories of particle physics in an attempt to solve some of the major unanswered questions in science. In this talk for Cardiff Astronomical Society, Professor Maurizio Piai of Swansea University reveals what the LHC means for scientific discovery. Members and visitors are welcome.

www.cardiff-astronomical-society.co.uk

MORE LISTINGS ONLINE

Visit our website at www.skyatnightmagazine.com/whats-on for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.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A PASSION FOR SPACE

with **Dr Michele Bannister**

`Oumuamua's brief visit instigated a frantic scramble to gather information on this interstellar wanderer

The cucumber-shaped `Oumuamua is the first confirmed minor planet to come from outside our Galaxy

ESO/M.KORNMESSER

Back in October last year, the Pan-STARRS (Panoramic Survey Telescope and Rapid Response System) telescope in Hawaii photographed a moving dot of light. That dot turned out to be a skyscraper-sized world, later christened 1I/2017 U1 `Oumuamua. It's the first interstellar minor planet to be seen, but our Galaxy must be full of wandering asteroids and comets like it, tossed out of untold billions of planetary systems as they were forming around stars.

Astronomy is international. At 6.30am on 25 October I saw the announcement of `Oumuamua's discovery – emailed from the International Astronomical Union's Minor Planet Center in Boston, which sends out notifications of new comets and asteroids. This institution is known for low-key gravitas, so I was astounded to read: "If further observations confirm the unusual nature of this orbit, this object may be the first clear case of an interstellar comet."

I tweeted a link to the news and went for my morning run. By the time I got back, a friend who was at the Palomar Observatory in California looking for asteroids was already observing `Oumuamua.

Travelling at a speed of 26km/s, nearly twice as fast as the fastest spacecraft yet launched, `Oumuamua was only close enough to be visible to the world's biggest telescopes for a few days. With a flurry of emails between colleagues in the UK and abroad, we asked for urgent observations to be made by telescopes big enough to study the object: the Gemini Observatory in Hawaii, the Very Large Telescope in Chile and the William Herschel Telescope in the Canary Islands.

Initial findings

Observations with these telescopes enabled us to gather a wealth of precious photons reflected from `Oumuamua's surface. This visible and near-infrared light encodes the composition of the top few microns of `Oumuamua's crust. After comparing this information with that collected by Col-OSSOS (COLours for the Outer Solar System Object Survey), which we've been using to map the surfaces of distant minor planets, it seems `Oumuamua could call these larger worlds its cousins. Like Jupiter's Trojan asteroids and some of the small worlds on inclined, eccentric orbits beyond Neptune, `Oumuamua is slightly reddish in colour relative to sunlight.

Its dry exterior has no trace of coma like a comet, but it could hide an icy heart: `Oumuamua's passage by the Sun, though inside the orbit of Mercury, was so fast that its surface only reached cake-baking temperatures. A scant metre of insulating organic-rich material (a composition suggested by its reddish surface) would be enough to prevent `Oumuamua becoming a comet by protecting any buried ice from the heat. Watching `Oumuamua over a few days showed a dramatic change in brightness: more than 1.5 magnitudes. That implies `Oumuamua has a cucumber-like shape, slowly turning to change the face we see.

This interstellar wanderer's home is not yet known. No star in the local neighbourhood matches its past trajectory. Like a piece of driftwood on the tide, it was scooped up by the Sun – an event that could have happened more than once at other stars. `Oumuamua has wandered the Milky Way for at least tens of millions of years, and may yet wander for billions more. Ⓢ

Planetary scientist Dr Michele Bannister is a regular guest on *The Sky at Night*

Maggie Aderin-Pocock is on holiday

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JON CULSHAW'S

EXOPLANET EXCURSIONS

Jon fires up the Perihelion for a trip to a gas giant with a glacially slow orbit

My destination this month is a most interesting, T-Tauri star named CVSO 30, which sounds like a form you'd find in a Post Office. The star of this system is 0.4 solar masses and very young – a stellar toddler just a mere 2.5 million years old. This extraordinarily fresh star takes its place in the constellation of Orion, 1,200 lightyears away.

There are two known worlds within this system, each as contrasting and extreme as it's possible to be. My ship, the Perihelion, will make only a brief flypast of the first planet, CVSO 30b, a great gas giant at five Jovian masses. Its extremely close proximity to the parent star of 1.2 million km means it completes a single orbit in a cosmic nano-blink of time – only 11 hours. The thought of this is utterly dizzying, though it does make for an interesting transit observation through my aluminised Mylar viewers. The planet slices through its orbital path like a Winter Olympics athlete on a luge.

Setting the Perihelion on a course much further from the star, I'm going to take a look at the other world we know in this system. Orbiting at an incredibly remote distance of 660 astronomical units from its star is CVSO 30c. In a tantalising step towards visualising interstellar objects, astronomers used the Very Large Telescope in Chile to obtain a direct image of this exoplanet. At 4.7 times the mass of Jupiter this is a mighty planet cloaked in a dim, bleak, dark environment.

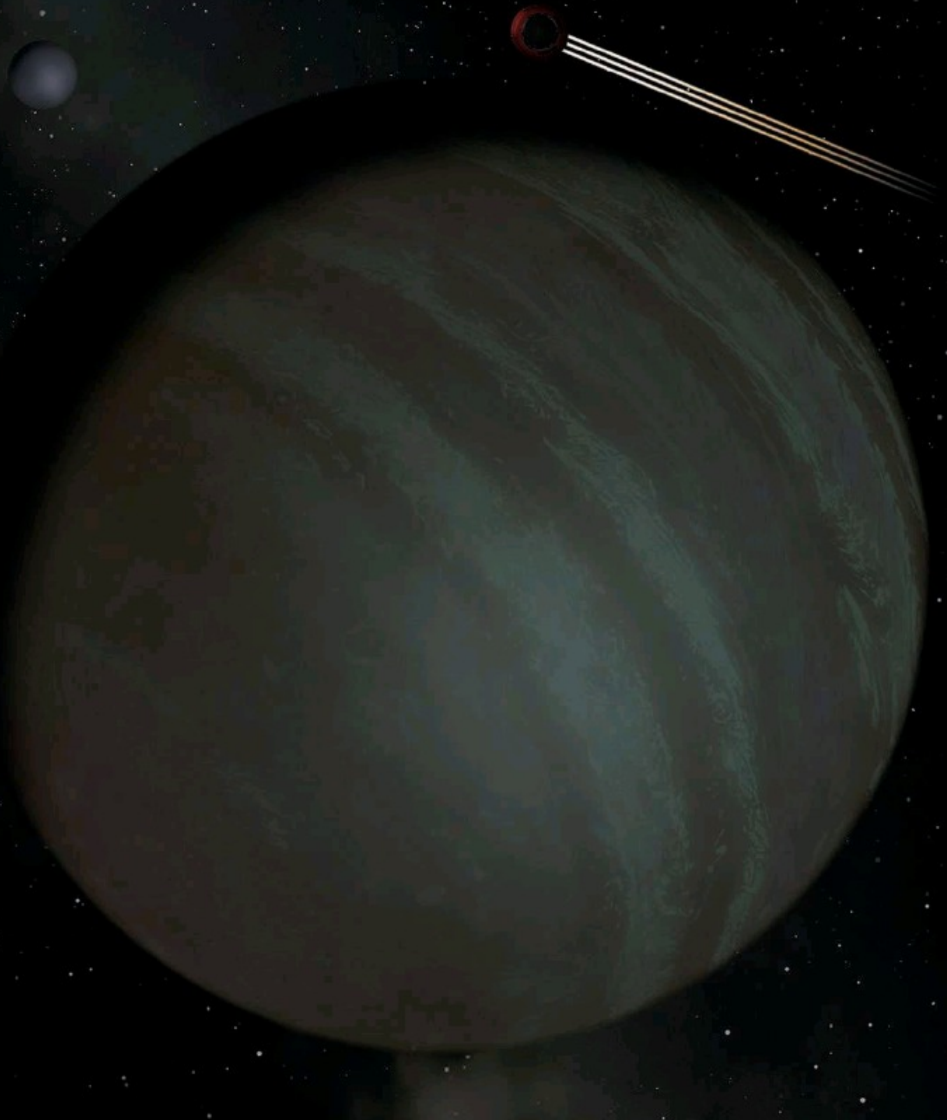
It's tough to contemplate the 27,000 years CVSO 30c takes to complete a single orbit – this planet has the chilling sense of time locked into perpetual stillness. The light from the distant star is minimal, offering scant reassurance; the view is like a blacked-out bedroom at 3am, lit only by the tiny LED on a rechargeable shaver.

The thought of this planet's year lasting 27,000 of our own is rather a stretch for me to imagine. When this world was last in its present position, the Earth was in the grip of its most recent ice age: mammoths, cave bears and Neanderthals occupied the deep-chilled lands. It feels like another form of ice age here, passing over CVSO 30c – a darker, stony, silent ice age with an eerie, almost maddening stillness.

Turning away from the dim flicker of the home star, the blackness of the sky allows a myriad unfamiliar constellations to zing into view with unpolluted magnificence. It's novel to consider that Orion isn't visible due to the fact we're in it. But that silence and stillness is like an unnerving void, and causes an unpleasant feeling the longer I remain in this location. It's almost a lonely vision of hell, such is the sense of condemned detachment and emptiness.

Time to hope the Perihelion keeps running and completes the 1,200 lightyear journey back to Earth! The urge to return home is strong on this trip.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*



MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

Interactive

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Email us at **inbox@skyatnightmagazine.com**

PHILIP'S COMPLETE GUIDE STARGAZ
PHILIP'S STARGAZIN WITH BINOCULARS
PHILIP'S Guide to THE NIGHT SKY
PHILIP'S 2018 STARGAZING

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *2018 Stargazing*.

Tales from THE EYEPIECE

Stories and strange tales from the world of amateur astronomy by Jonathan Powell

In the 1980s I headed up my very own space programme (from my parent's back garden) called Vega. It was similar to the Soviet project, but didn't yield the same success. Over a year I made a succession of rockets using bits and bobs. They measured no more than 15 inches in height once placed on the launchpad (a garden shed base). A word of warning: please seek out professional rocketeers if you wish to get involved in rocketry, such as Finns Over Gwent, based in South Wales. Most of my launches were scheduled for afternoon slots, but I reserved one for an evening so that my friends could watch. Needless to say my rockets never took flight, apart from my last attempt, which I lifted off rather successfully from the end of my boot!

Jonathan Powell is the astronomy correspondent for the South Wales Argus

MESSAGE OF THE MONTH

The eyepieces have it

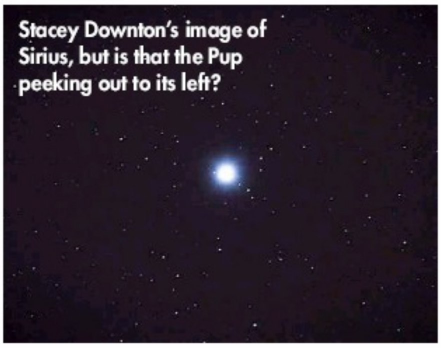
Much is written about how upgrading eyepieces (EPs) has a positive impact on the observing experience, and as a result I decided to purchase some better versions. After a bit of searching I took delivery of a BST StarGuider 8mm and a 2-inch Explore Scientific Maxvision 68° 28mm EP. Naturally, as soon as they arrived so did the cloud! After a fortnight's wait the clear sky came and my EPs got their first light on the Orion Nebula and M31.

The difference in quality of view between the new EPs and the ones that came with the telescope was astounding: the clarity and contrast of the nebulosity was fantastic; the definition I was able to observe on M31 likewise. Before packing away I cast about the skies a bit and found myself wandering towards Cassiopeia. As I did so, with the 28mm in the focuser, I stumbled across something that took my breath away. It may have been NGC 7789 (Caroline's Rose), as mentioned in Will Gater's article in February's magazine, 'Sparkling Diamonds of the Winter Sky'; it may have been something else. Whatever it was, it was a fantastic field of stars, the clarity and brilliance of which I had never seen before. This sight alone made the outlay for the EPs worthwhile. I may have to improve my EP collection further.

Matt Langridge, Marlow, Buckinghamshire

▲ Upgrading your telescope's eyepieces is a great way to invest in better views

I couldn't agree more, Matt: I never regret having invested in quality eyepieces. If you have a fairly decent telescope it's one of the best upgrades you can make. **– Ed**



Stacey Downton's image of Sirius, but is that the Pup peeking out to its left?

Have I shot the Pup?

I'm fairly new to astrophotography but on 7 January in Birmingham (Longbridge to be exact) the seeing conditions were perfect. So good, in fact, that I could see a faint echo of the Orion Nebula with the naked eye from my back garden. Later in the evening, when my scope and camera had been outside a long time and had cooled down to around –2°C, I focused in on Sirius, quickly shot an image and posted it on Facebook, where it promptly took off! Some were saying I might have captured Sirius B in my image. My scope is a modest 80mm apochromatic refractor, but I've checked on my planetarium software and the two images seem to match up. Can you help give me a yes or no either way?

Stacey Downton, via email

Chances are that tiny star to the left of Sirius in your image isn't the Pup, I'm

SOCIETY in focus

▲ **Kids and parents at Bristol AS's Young Persons Astronomy Course held in December**

Bristol Astronomical Society ran its first Young Person's Astronomy Course in December. Spread over four weeks and aimed at 10-14 year olds, the evening classes covered naked-eye, binocular and telescope observing, astrophotography and astronomical theory.

"Whenever we set up our telescopes at star parties and festivals in the city we're always asked what we do for kids, so we organised this course," says club chairman Richard Mansfield. "What was clear is that the kids loved looking through the different telescopes, especially when we had them linked to iPads, phones and computers for live viewing," he revealed.

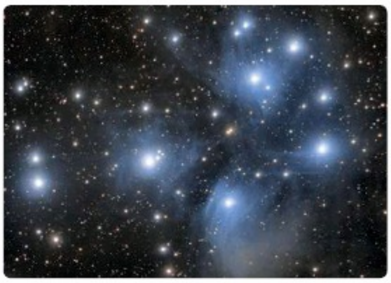
Course attendees Denise Blair and daughter Evie, 10, enjoyed visiting the society's observatory west of the city. "We went up to the observatory and set up telescopes, then looked through them at Andromeda and the Moon," said Evie.

Other attendees enjoyed learning about why stars shine and how planets form. "My son is a science geek but we're not science parents, so it's been great for us to know things that keep him interested," said mum Alison Thiru, at the course with son Namish, 9.

Bristol Astronomical Society's next Young Person's course will be held on 23 February and 2, 9 and 16 March. For more details visit **www.bristolastrosoc.org.uk**

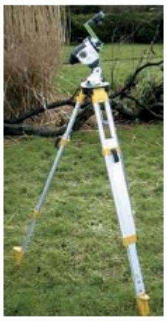
Tweets

Raoul
@UKAstroNerd • Jan 15
#M45 – #ThePleiades – Seven Sisters. Imaged from #Oxfordshire during the winters of 2016 & 2017 using a guided 80mm Refractor.
@skyatnightmag #Astronomy #AstroPhotography



afraid, Stacey. It's probably a mag. +15 star about 120 arcseconds from Sirius that's aligned with it and the Pup. Since the Pup is only 10.9 arcseconds from Sirius, it's likely that it's been drowned out by Sirius's glare in your image. Don't let that put you off though – keep trying to glimpse the Pup and you'll get plenty more great images like this one! ***– Ed***

The eBay alternative



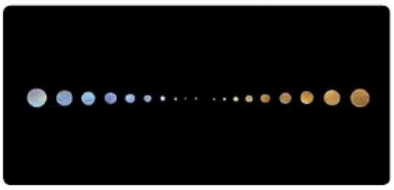
In January's 'Scope Doctor', Paul Shiels asked about a new mount for his Sky-Watcher Heritage 130P table-top telescope. My solution for a stable mounting was to buy a second-hand Leica surveying tripod, which you can pick up for only £50 on eBay. I already had a Sky-Watcher Star Adventurer tracking mount, which I attached to the tripod with a 10cm length of 3/8-inch threaded rod, a washer and large wingnut. The end result is rock solid – perfect for my tracking kit.

Dave Hardcastle, via email

Thanks for the tip, Dave. I've no doubt your setup is rock solid: those surveying tripods really do look stable. ***– Ed***

Tweets

Roger Hutchinson FRAS
@roger931 • Jan 8
The colours of the stars Rigel & Betelgeuse shot from London last night (7th). 10 shots each with successive de-focus. Thanks to @willgater & the latest @skyatnightmag for the inspiration! #orion #rigel #betelgeuse #stars #astrophotography #space #london #astronomy



Meanwhile on FACEBOOK...

WE ASKED: Iridium flares are soon to be no more (see p74). Will you miss them?

Stuart Atkinson
I'll really miss them. It's been great fun watching them, planning where to look for them, trying to get photos of them. Very frustrating too, when an exposure ended just before the flare appeared, but I've never grown bored of them, and they're great for showing non-astronomers during public outreach events too.

David Gosnell
They've been a handy party trick once or twice. Will miss them.

Kelvin Ong
Whenever I head north to my neighbouring country, away from the disgusting polluting city lights, I always see these light up the dark sky while waiting for a real meteor.

Craig Mathieson
The sight of a flare flickering as it passed in and out of the shadows cast by the mountains of Northern Ireland over the horizon is unforgettable. I hope they will send up new satellites with mirror coatings to replace the Iridium ones. Perhaps if we all campaign to bring back the flares!

Keith Moseley
Will miss them. Telling the uninitiated to watch the sky at certain times made me look like a magician.

Peter McCarthy
Too much light pollution here to see them, which is a pity.

Michael Boschat
They were interesting and at public observing sessions some people thought they saw a meteor. I could always tell them what it was. Even getting one on a photo was not bad.

Malcolm Haswell
I was so pleased to catch one over the rooftops a few months ago but they can be frustrating to photograph (even with an app to predict them). I guess I'll just have to take some better shots of the ISS then.

OOPS!

In our feature 'Go For Launch' on page 69 of the January issue we said, "CNSA could also send the first-ever uncrewed sample return mission to the lunar near-side, Chang'e 5…", when what we meant was, "CNSA could also send its first-ever uncrewed sample return mission…". As reader Frank Ellis wrote to point out, the first uncrewed sample-return mission to the Moon was the Soviet Luna 16 mission in 1970, which brought back 101g of lunar soil from its landing site 150km north of Crater Langrenus.

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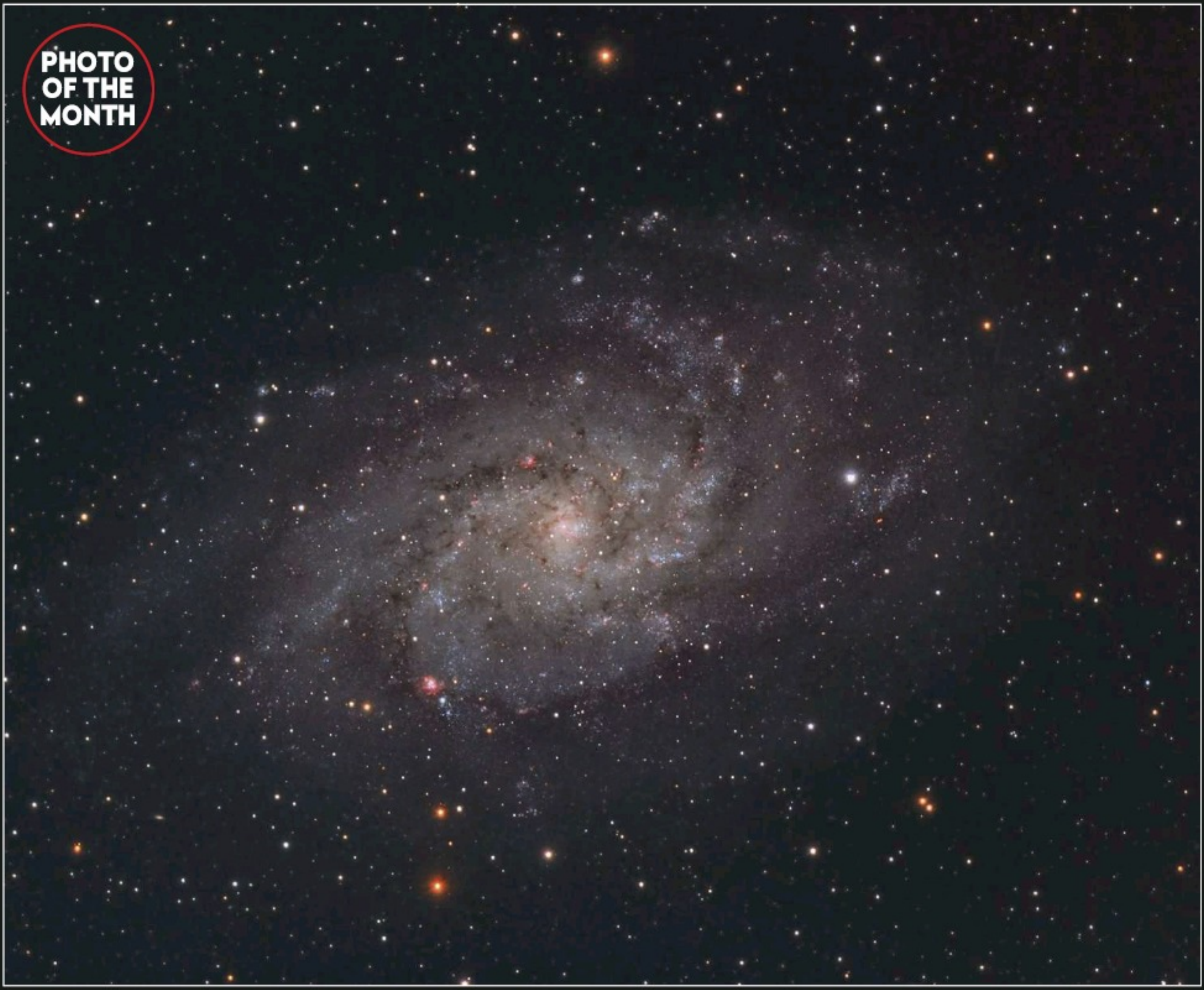
Hotshots

This month's pick of your very best astrophotos

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images



▲ The Triangulum Galaxy

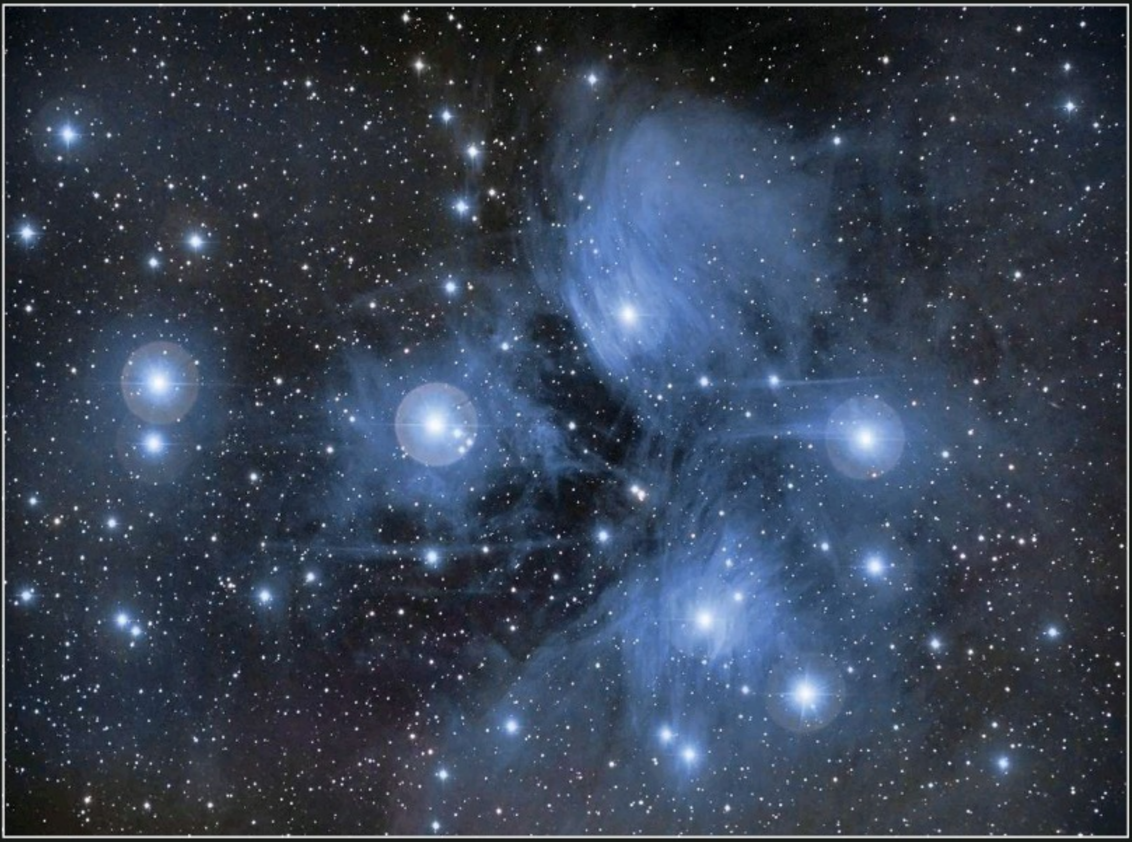
ALEC ALDEN, COLCHESTER, 17, 18, 24 AND 25 NOVEMBER 2017

Alec says: "This image is a combination of the subs from two set ups. I had about five hours of LRGB subs taken in September 2016 and I decided to add to these with a further five hours of LRGB subs taken in November 2017 with my new rig. The processing was carried out using Pixinsight, which I find incredible, but it is easy to fall into the trap of over-processing images. This image came together without any problems though."

Equipment: Atik 383L+ mono CCD camera and Sky-Watcher Evostar 80ED refractor, ZWO ASI 1600MM mono camera and Sky-Watcher 120ED Equinox refractor.

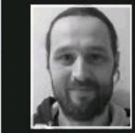
***BBC Sky at Night Magazine* says:** "We were immediately drawn to the beautiful colours Alec has managed to capture in this image: red pockets of ionised hydrogen gas from stellar formation, mingled with bright blue stars. Note too the definition in the spiral arms and wisps of dark cosmic dust."

About Alec: "In 2013 my family bought me my first telescope, a Sky-Watcher Heritage 130P. I soon found that I wanted a record of the astronomical objects I was observing and so I quickly moved into astrophotography. Deep-sky objects are my preference, although I like imaging whatever is visible in the sky. My set up allows me to take images with only occasional trips out into the cold. As I'm now retired, this hobby keeps me and my brain active and I'm constantly in wonderment at the scale of our Galaxy."



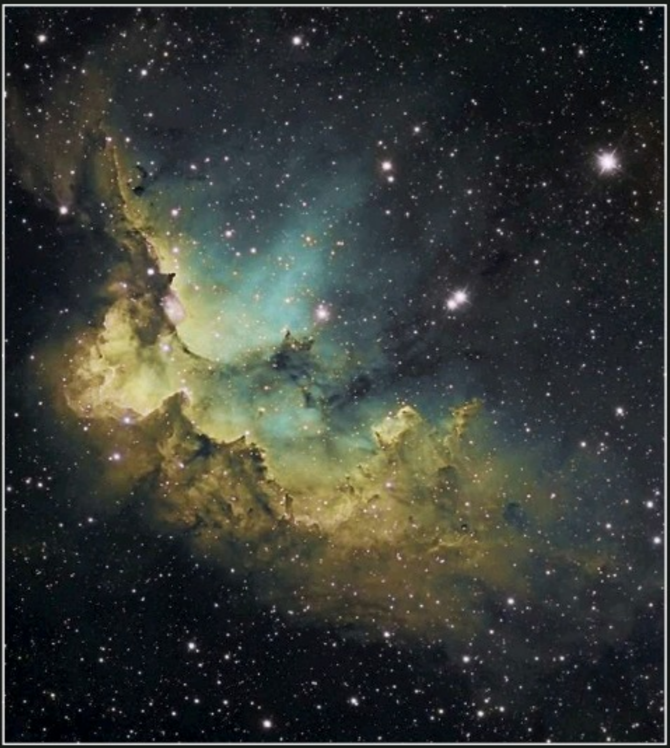
◀ The Pleiades

JASON WISEMAN, DEVON, 17 DECEMBER 2017



Jason says: "The skies in Torbay are heavily light polluted so a UHC filter and some subtle processing were necessary to bring out the nebulosity. I'm very pleased with the results and am looking forward to more clear nights."

Equipment: Canon EOS 550D DSLR camera, Celestron C14 EdgeHD Schmidt-Cassegrain, HyperStar lens, Sky-Watcher EQ8 mount.



▲ The Wizard Nebula

DUAN YUSEF, ESSEX, 1 NOVEMBER 2017

Duan says: "I'd photographed the Wizard in 2016 but I wanted to try and do a better job, so I really went for it and managed 19 hours of 10-minute exposures over a week. I used the Hubble palette method to combine the three colour channels and processed it in Photoshop."

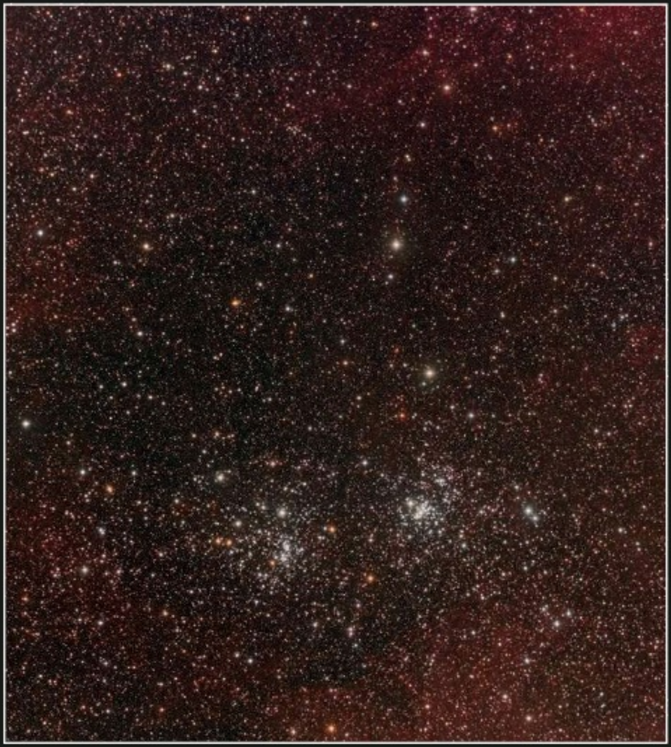
Equipment: ZWO ASI 1600MM cooled mono camera, 10-inch truss tube Ritchey Chrétien telescope, Sky-Watcher EQ8 Pro mount.

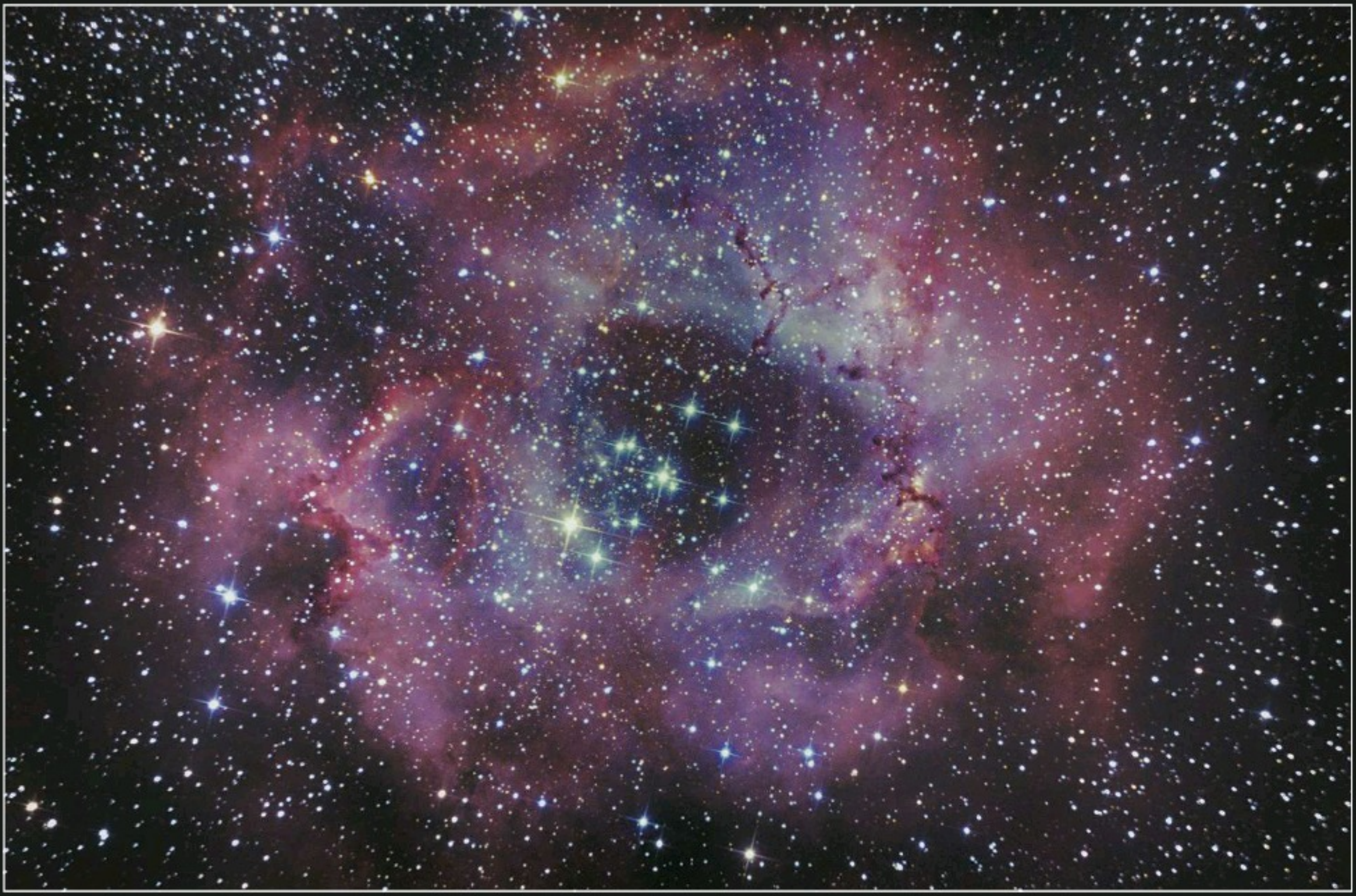
▼ Caldwell 14

MATTHEW FOYLE, DERBYSHIRE, 11 DECEMBER 2017

Matthew says: "This was a difficult image to get from my location and required a good night. I imaged for over 12 hours but had to throw away around two hours: I fell asleep in the early hours of the morning and the scope wound up pointing through the trees in my back garden."

Equipment: QHY9M CCD camera, Takahashi FSQ-106ED refractor, Sky-Watcher EQ8 Pro mount.



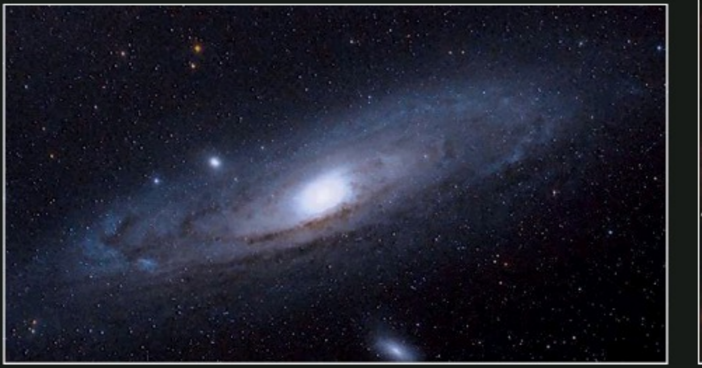


▲ The Rosette Nebula

GERARD TÀRTALO, LLEIDA, SPAIN, 16 DECEMBER 2017

Gerard says: "I chose this target because I hadn't photographed it before and it's a beautiful nebula that fits well in my field of view. Perhaps the biggest problem was the excessive coma in the stars around the edges, caused by the aberration of the Newtonian's parabolic primary mirror."

Equipment: Canon EOS 600D DSLR camera, Sky-Watcher 150/750 PDS Newtonian, Sky-Watcher NEQ6 Pro mount.

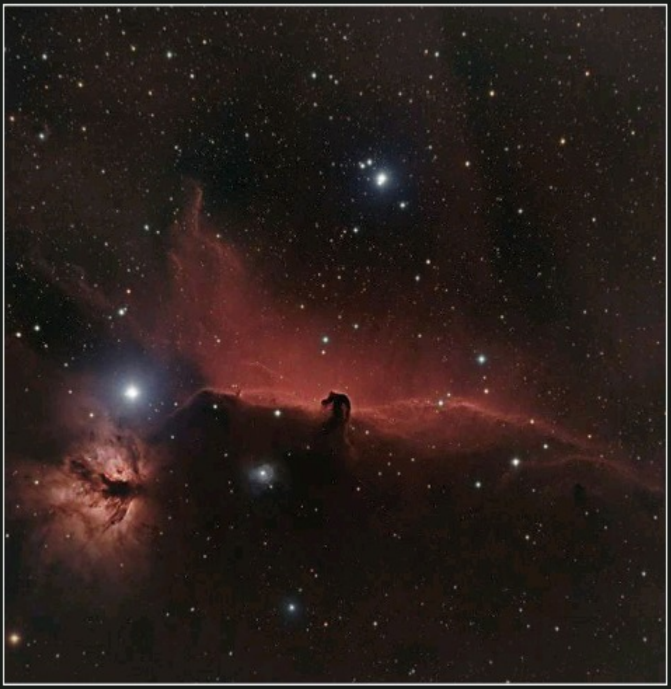


▲ The Andromeda Galaxy

MATTHEW DOWNES, BRIGHTON, 8 DECEMBER 2017

Matthew says: "This was my first try at capturing an image with my tracker so I'm pleased with the result. In the past, I've had to drive for an hour to find dark skies when taking Milky Way photos, so when I realised I could get a shot like this from my back garden I was over the Moon."

Equipment: Nikon D750 DSLR camera, iOptron SkyTracker mount, 70-200mm lens.

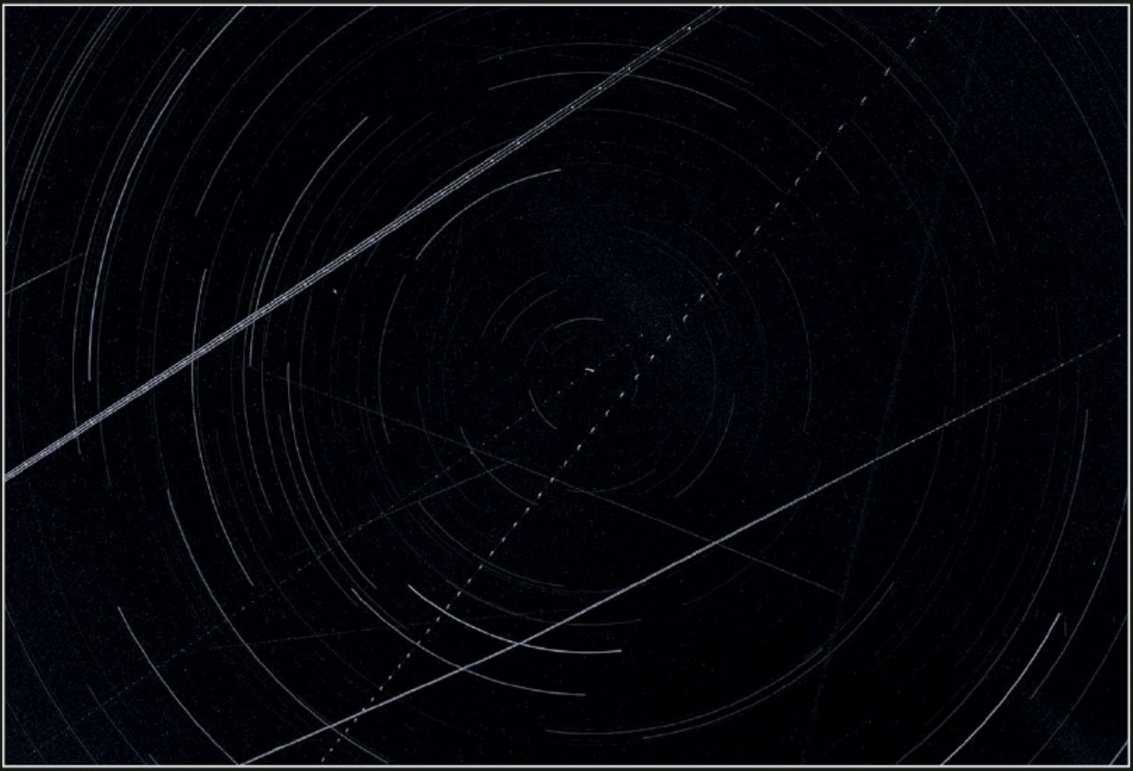


▲ The Horsehead Nebula

SIMON HUDSON, LONDON, 17 NOVEMBER 2017

Simon says: "The Horsehead is one of my favourite targets. I added some H-alpha to punch through the London skyglow and pick out some fainter detail. Using H-alpha as a luminance layer helped solve some of the problems of imaging from a city and I'm pleased with how it came out."

Equipment: QHY9 mono CCD camera, Explore Scientific ED80 refractor, Celestron CGX mount.



◀ Star trails

DARREN FELGATE, NORTH YORKSHIRE, 16 DECEMBER 2017

Darren says: "I captured this as one image over a four-hour period (hence the number of aeroplane trails) and edited it using the Snapseed app to darken the sky and bring out some colour variations in the star trails."

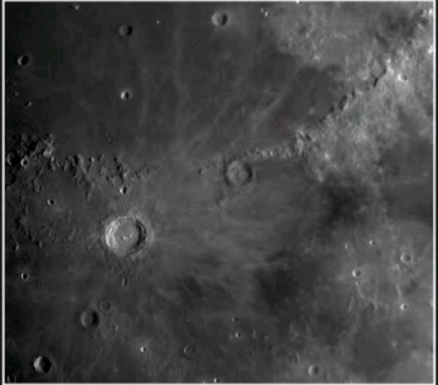
Equipment: iPhone, tripod, NightCap app

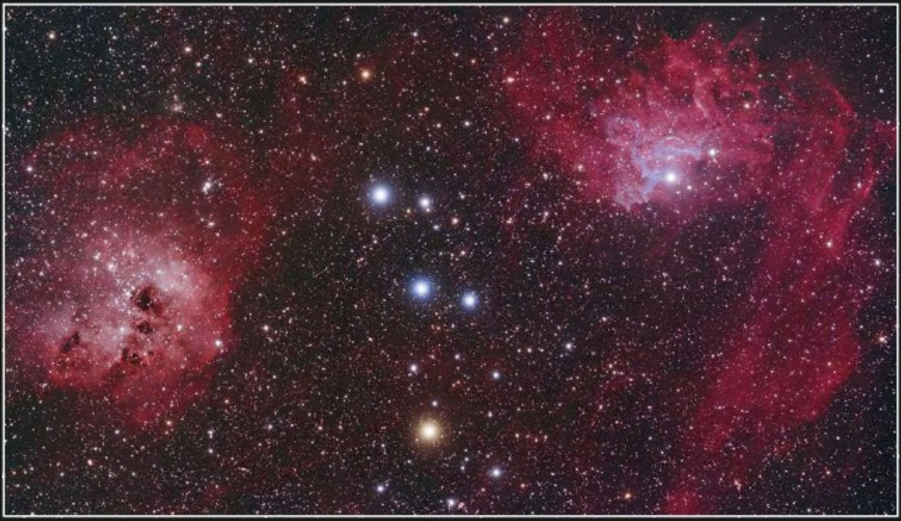
▼ Copernicus and Eratosthenes

ALEX HOUSTON, CLACKMANNANSHIRE, 28 DECEMBER 2017

Alex says: "My intention was to capture as much of the Moon as possible in two hours and I managed to get 72 AVI files of the lunar surface. A section of the mosaic was cropped to produce the final image."

Equipment: ZWO ASI 120MM-S mono camera, Sky-Watcher Evostar-100ED2 Pro refractor.





▲ Tadpole and Flaming Star Nebulae

GÁBOR SZENDRÓI, KENDIG, HUNGARY, 18 DECEMBER 2017

Gábor says: "As these emission nebulae rise in the evening in December and are visible throughout the winter nights, my father and I decided to capture them in a wide-field image. Circumstances were ideal for a long session of astrophotography and, despite the cold, we managed to get a total exposure time of six hours."

Equipment: Canon EOS 700D DSLR camera, GPU 100/635 apo refractor, Sky-Watcher AZ-EQ6 GT mount.

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ABOUT THE WRITER
Lucie is a Professor of Physics and a Royal Society University Research Fellow based at the Mullard Space Science Lab

The magnetic UNIVERSE

Lucie Green takes a closer look at how magnetic fields have shaped the cosmos

SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO

You can't see it, but it's there. All the time, and all around you. Protecting you from harmful space radiation and preventing our atmosphere from being stripped away by solar winds – it's the Earth's magnetic field.

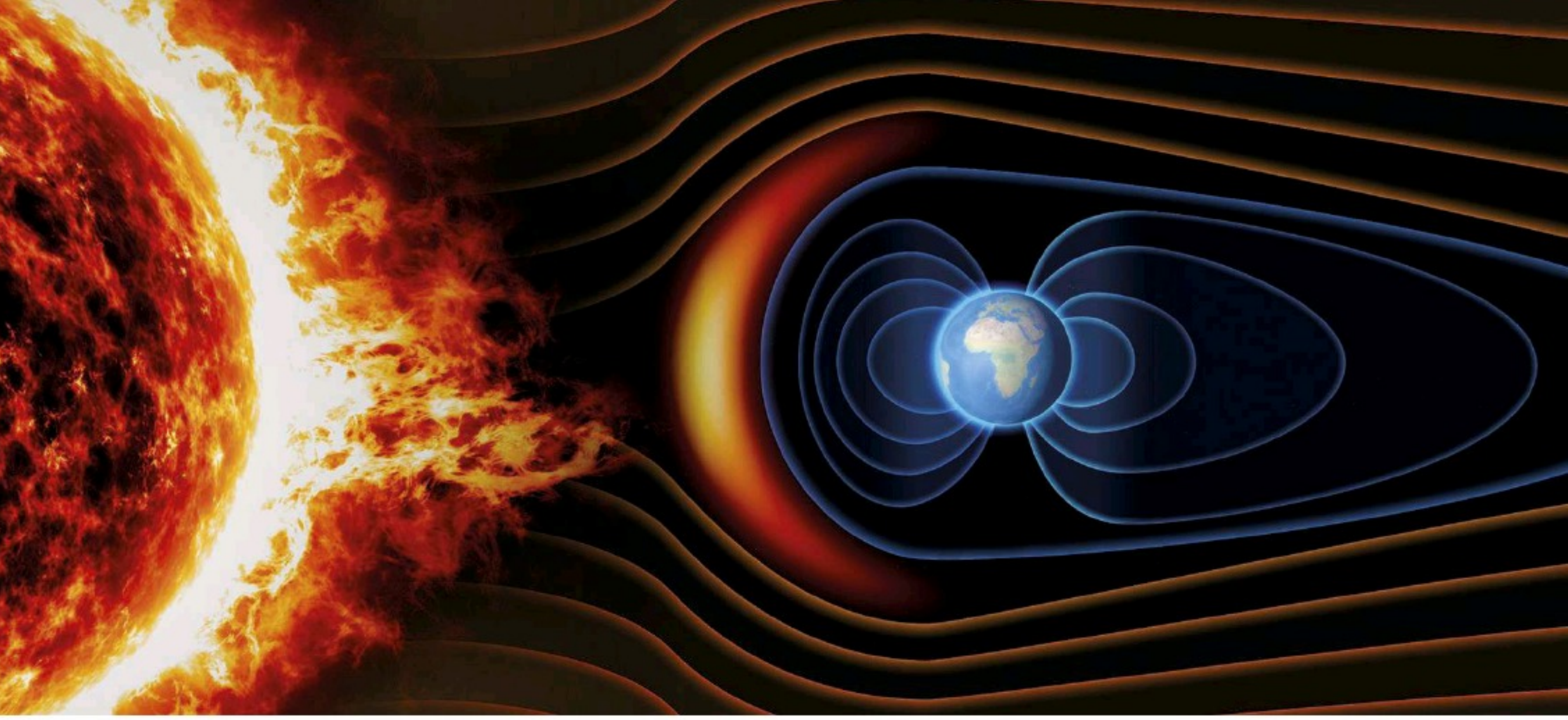
For most of us, it hardly ever catches our attention. In observational astronomy, the Earth's magnetic poles are far less important than the geographic poles that we rely on to align our equatorially mounted telescopes. Consider this, though: the Earth's magnetic field probably made life on this planet possible, while more distant, cosmic magnetic fields are the reason that pulsars act like radio lighthouses and vast clouds of electrically conducting gas get sculpted into strange and unusual shapes.

As magnetic fields go, Earth's is the one we're most familiar with and its origin lies in the electric currents that flow in the molten iron that makes up our planet's outer core.

Planetary magnetism

Let's take a step back and look at Earth from the surface of the Moon. From here, we can see the land, oceans and atmosphere. What we can't see, however, ▸

The dynamo effect of the Earth's spinning molten core produces our planet's magnetic field, which prevents the solar wind from stripping away our atmosphere



▲ Earth's magnetic field protects us from the solar wind, which energises particles in our atmosphere and produces the aurora

ISTOCK X 2, NASA'S GODDARD SPACE FLIGHT CENTER, NASA

▸ is how the Earth's magnetic field envelops it all and extends out into space. For most of the time the Moon is inside the Earth's magnetic field. It only pops out for a few days around the time of new Moon. When it does, the Moon moves into the solar wind – the Sun's outer atmosphere that expands into space at a speed of a million miles an hour.

This wind can't penetrate Earth's magnetic field and instead slams straight into it. Although this interaction is invisible to the human eye, it does produce something spectacular: the aurora. As the solar wind pushes against Earth's magnetic field, it adds energy to it that accelerates charged particles down into our atmosphere. When the particles interact with atmospheric gas, they pass their energy on and cause the gas to glow.

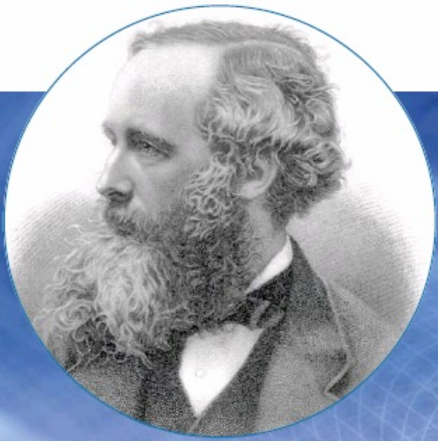
The solar wind is blocked from reaching our atmosphere because it too contains a magnetic field. We've learned that any magnetic field that threads through an electrically charged gas (a plasma) is tied to that gas; they can't be easily separated, or decoupled, as the process is known. So when the gusty flow of magnetised plasma reaches the Earth's magnetic field, it flows around it, causing it to move and ripple like a windsock in a breeze. This property prevents the solar wind from reaching our atmosphere and stripping it away, as happened on Mars. It also provides us with protection from electrically charged cosmic rays.

This life-preserving property that planetary magnetic fields have means that it's important to consider them when it comes to studying exoplanets. So far, we're unable to directly observe an exoplanet's magnetic field. But should a technique for detecting them be developed in the future, the presence of a magnetic field around an

The history of magnetic astronomy

The journey to uncovering the magnetic fields throughout our Universe has taken many centuries

1600 – William Gilbert, the first person to investigate magnetism using scientific methods, publishes his work in a volume titled *De Magnete*.



1865 – Physics Professor James Clerk Maxwell publishes a paper in which he unifies the areas of electricity and magnetism into a single theory.

1901 – Norway's Kristian Birkeland begins building "Terrellas" (little Earths) to test his theory that the aurora are formed by electrons hitting Earth's magnetic poles.

"The Sun allows us to investigate cosmic magnetism up close. We get a fantastic level of detail that really shows us how dynamic stellar magnetic fields can be"

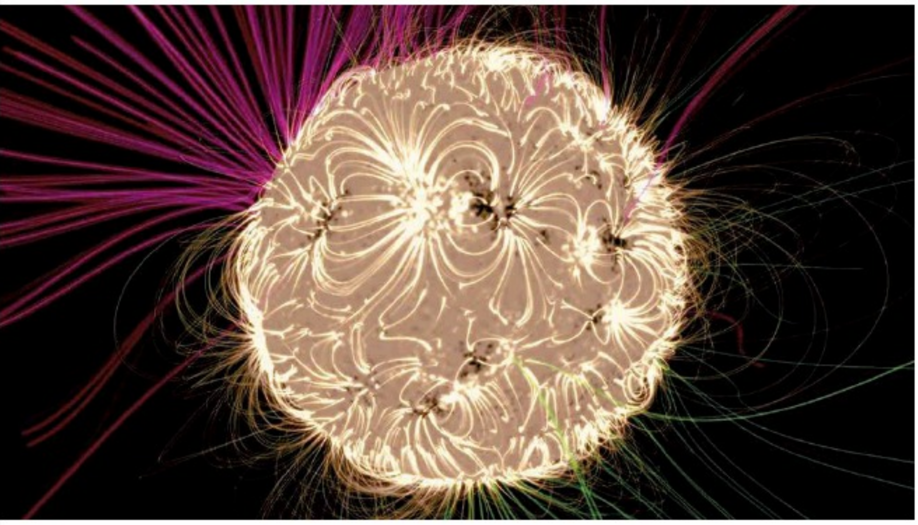
exoplanet is likely to influence which ones become targets for further study.

The discovery of the Sun's magnetic field came in 1908 and was made by American astronomer George Ellery Hale. It's impossible to look for and study cosmic magnetic fields without the ability to detect them from a distance using electromagnetic radiation. In 1896, Dutch physicist Pieter Zeeman was carrying out experiments when he found that a strong magnetic field could affect the light given off by a "luminous vapour". The spectral lines emitted by the vapour were broadened or, in extreme cases, split into several components. In a paper published in 1897, Zeeman suggested that his discovery might be used to detect cosmic magnetic fields.

Indeed, it was this technique that was used by Hale to detect the magnetic field of sunspots. The Zeeman effect also polarises the light in particular ways that can be used to understand the strength and direction of the distant magnetic field, allowing astronomers to probe distant magnetism by studying electromagnetic radiation.

In fact, the Sun allows us to investigate cosmic magnetism up close. Observations of the Sun provide a fantastic level of detail that really shows us how dynamic stellar magnetic fields can be. The Sun has an overall magnetic field that connects the north and south magnetic poles, which are close to the heliographic north and south poles, as they are on Earth.

▾ **Flux ropes, magnetic fields arching between sunspots, can be revealed by the glowing, charged gas tracing their paths**



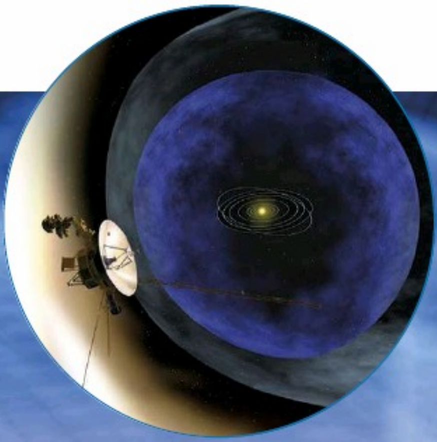
Small-scale magnetism

But closer inspection of the solar atmosphere reveals arches of magnetic field connecting pairs of sunspots and twisted magnetic field structures known as flux ropes. These ropes are revealed because glowing, electrically charged gas traces them out, similar to the way iron filings sprinkled around a bar magnet align themselves to the field lines. If you watch the Sun over time you'll see that these magnetic structures are always changing and often erupt into the Solar System. The Sun's spatially resolved dynamic activity, powered by magnetism, gives us a glimpse of what other stars are also up to. And it's not just main sequence stars that have important magnetic fields.

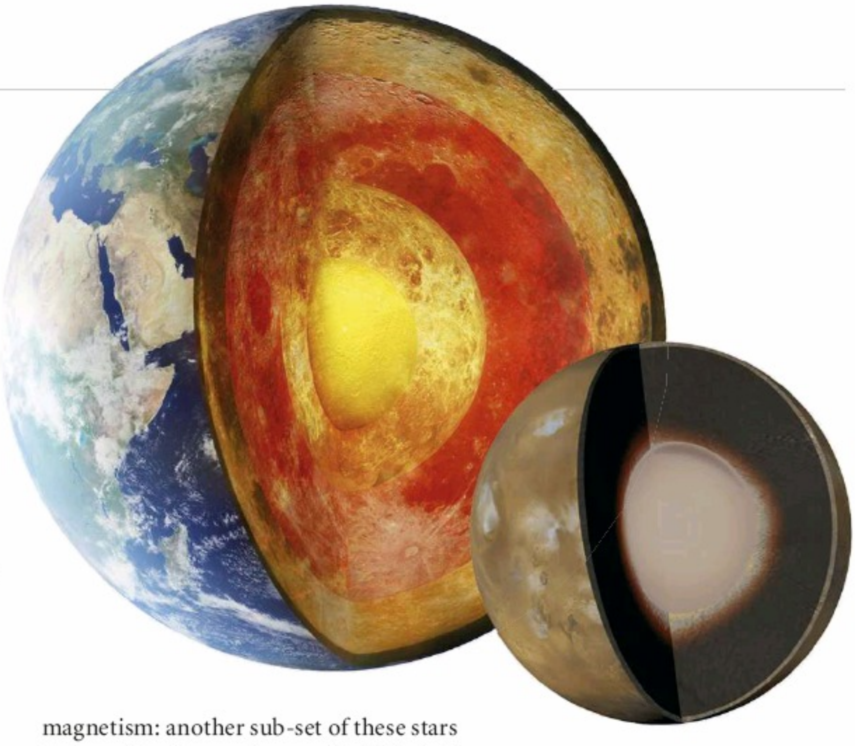
Pulsars are a sub-set of neutron stars. Formed from the collapsed cores of high-mass stars that ▸

1908 – American astronomer George Ellery Hale discovers magnetism on the Sun, providing the first evidence of magnetic fields beyond the Earth.

1942 – Swedish physicist Hannes Alfvén theorises that when a magnetic field threads through an electrically conducting gas, they become inseparable.



2012 – After 35 years travelling through space, the Voyager 1 spacecraft finally exits the Solar System as it leaves the Sun's vast bubble of magnetism behind.



▲ The spinning of Earth's hot, molten interior keeps its magnetic field strong, whereas Mars's cool, solid core makes its magnetic field much weaker

▸ have undergone a supernova explosion, they spin extremely rapidly. As they spin, they flash out pulses of radio waves, as if they were cosmic lighthouses. Some of them flash many times a second. When Jocelyn Bell-Burnell discovered pulsars in 1967 they were viewed as curious objects and jokingly labelled LGM for Little Green Men. But the radio flashes can be understood if you combine a very rapidly spinning star with a strong magnetic field.

As a dying star collapses, its magnetic field is also drawn in with the material of the star itself, intensifying the field strength to a trillion times that of the Earth's. The presence of the field causes charged particles to gyrate around the magnetic field lines and when this happens, radio waves can be created. The radio signal will be concentrated at the north and south magnetic poles of the neutron star. The final ingredient in the making of a pulsar is to have an offset between the star's axis of rotation and the axis connecting the magnetic poles. This means that as the neutron star spins, the radio beam will sweep across space and our radio telescopes can detect it. In fact, neutron stars are record holders when it comes to magnetism: another sub-set of these stars harbour the strongest magnetic fields in the Universe, a thousand times stronger than that of the pulsars. These objects are rather unsurprisingly known as magnetars.

Galactic magnetism

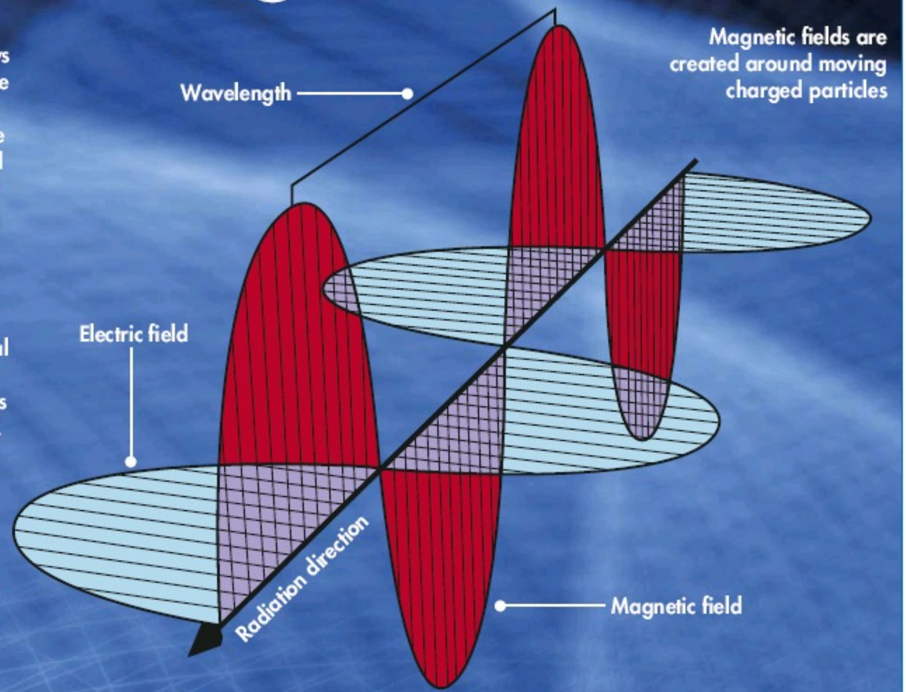
The magnetic field of Earth and the magnetic field of the Sun, thanks to the solar wind, are not the only fields we find ourselves immersed in. Our Galaxy, the Milky Way, has a magnetic field too, albeit with a strength tens of thousands of times less than that of the Earth's. What the galactic field does have in common with the Earth, though, is that rotation is at the heart of its existence.

What are magnetic fields?

Magnetism is a force that is intimately related to electricity. Whenever an electric current flows there will be an associated magnetic field in the surrounding space, or more generally, the movement of any charged particle will produce a magnetic field. Try turning your kettle on and off and see if your smartphone's compass app can detect the magnetic field generated as the current runs through the cable.

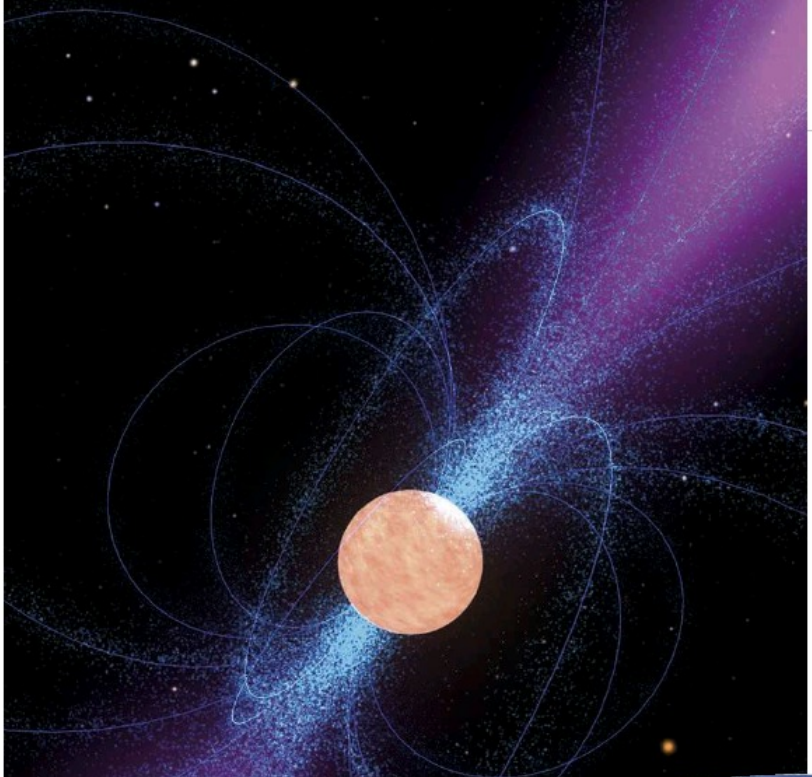
These fields have a direction, which is why Earth has a north and a south pole. When two magnetic fields come close to each other, they will try to align, potentially causing the physical objects causing them to move – a compass needle has a magnetic field, and so will always try to line up with Earth's field and point north.

Similarly, the motion of a charged particle will change as it passes through a magnetised area, due to the interaction of the electric and magnetic fields. How the direction changes depends on the charge and mass of the particle, the strength and direction of magnetic field and how fast the particle is travelling.



Magnetic fields are created around moving charged particles

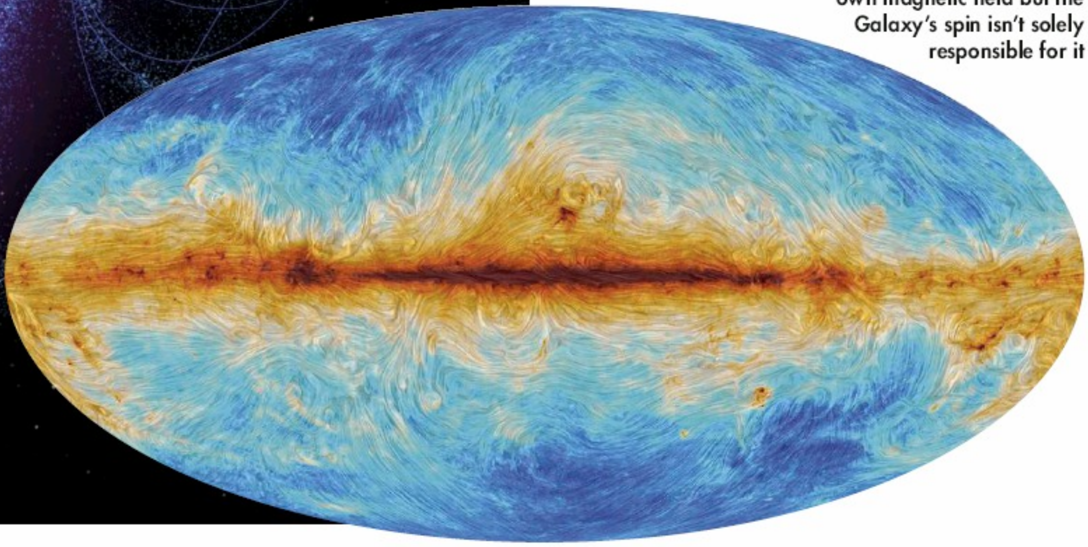
ISTOCK X 2, COURTESY NASA/JPL-CALTECH, ILLUSTRATION BY PAUL WOOTTON, NASA, ESA AND THE PLANCK COLLABORATION



▲ A pulsar's beams sweep across space because the axis of its magnetic poles isn't aligned with its axis of rotation

> "One question that astronomers have long wanted to answer is how long magnetic fields have existed for"

▼ The Milky Way has its own magnetic field but the Galaxy's spin isn't solely responsible for it



Magnetic fields in astrophysical objects are created by dynamos, a mechanism in which the rotation of an electrically conductive liquid (such as the molten iron in the core of a planet) is converted into magnetic energy. In this way, how fast an astronomical object spins is an important aspect of magnetic fields and dynamos.

In this context we can understand why Earth has a relatively strong field whereas Mars, once thought to be more Earth-like than it is today, doesn't. Inside Earth, the rotating molten shell means its dynamo is still acting. Mars, on the other hand, had a dynamo, but it ceased acting when the interior of this smaller planet cooled and solidified, leaving only a remnant of its magnetic field locked up in its rocks.

When it comes to timescales, stars and planets can take anything from hours to weeks to complete a single rotation. But these bodies have been around for so long that plenty of time has passed during their lifetimes to sustain and even evolve their magnetic fields. For example, the Sun rotates once every 27 days and has been around for 4.5 billion years. Assuming that the rotation rate has been constant during all of this time, the Sun could have spun over 60 billion times. This isn't the case when it comes to galaxies though. Take the Milky Way: our Galaxy rotates once every few hundred million years, which means there has only been time for it to make a few hundred rotations. So, while a dynamo is important for our Galaxy, there are other additional processes that are making an impact and which still need to be understood.

In 2017, a team led by scientists from the Max Planck Institute for Radio Astronomy in Germany published work showing that galaxy observations can be used to investigate magnetic fields when the Universe was much younger too. Their study of a galaxy that is nearly five billion lightyears away allows us to look back into the early Universe to study the history and evolution of magnetic fields, providing insight into a question that astronomers have long wanted to answer: how long have magnetic fields existed for?

Magnetic fields are magnificent and common across the cosmos. From planets and stars, to galaxies and beyond. Along with gravity, magnetism is responsible for shaping and controlling what we observe. So, next time you look up – no matter what you're looking at – remember the invisible force that is helping shape our Universe. Ⓢ

A collision between two neutron stars and the effects observed in the aftermath have opened up a new way for astronomers to scrutinise astronomical events

RIPPLES RADIATION & REVELATION

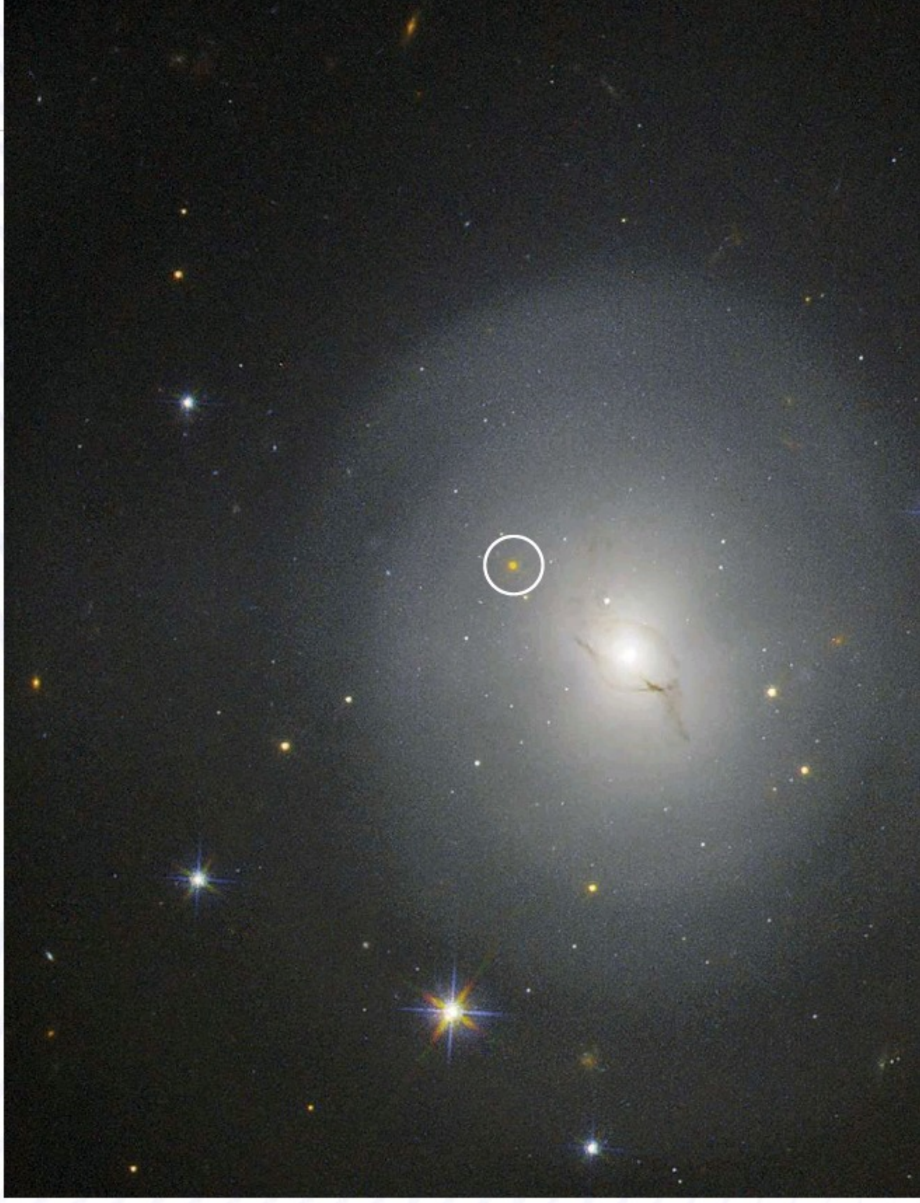
A revolution that began with colliding neutron stars is taking place in astronomy. **Will Gater** looks at how electromagnetic and gravitational wave observations are expanding our view of the cosmos

ABOUT THE WRITER
Will Gater is an astronomy journalist, author and presenter. Follow him on Twitter at @willgater or visit willgater.com

Every so often, a true moment of scientific insight comes along, a moment that has a profound impact on how we explore the Universe. One such moment came in 2015 with the first detection of gravitational waves – ripples in the fabric of space-time that propagate from moving celestial bodies and violent events such as the merging of two black holes or neutron stars.

But despite the astronomical possibilities gravitational waves grant us, it was another, more recent, observation that opened up a new field of space science. That new field is multi-messenger astronomy, in which the secrets of the Universe are revealed through detecting and observing not only electromagnetic radiation, but gravitational waves and other celestial phenomena too. And its story begins around lunchtime, in August last year. ▸

ESO/L. CALÇADA/M. KORNMESSER



▸ At 12:41 UT on 17 August 2017, the Laser Interferometer Gravitational-wave Observatory (LIGO) detectors in Washington and Louisiana, USA, sensed a gravitational wave washing over their respective sites. What happened next would thrill researchers and set off a dramatic chain of events.

Mere seconds later, in space, NASA's Fermi Gamma-ray Space Telescope and ESA's International Gamma-Ray Astrophysics Lab (INTEGRAL) satellite both caught a burst of gamma-rays emanating from somewhere in the southern celestial hemisphere. Could the two things be related?

"Less than a minute after the gamma-ray [burst] was picked up by the Fermi team, they notified everyone else that they'd seen something interesting and gave a rough sky map of the location," recalls Dr Michalis Agathos, a LIGO-Virgo Collaboration researcher based at the University of Cambridge.

The scramble to correlate

As news of the gamma-ray burst started to reach astronomers around the world, the LIGO researchers were already analysing the wave their detectors had sensed, which they'd now catalogued as GW170817. Like the Fermi and INTEGRAL teams, the LIGO researchers notified collaborators at astronomical organisations around the world with access to telescopes observing across practically the entire electromagnetic spectrum.

Astronomers and gravitational wave researchers have started to work together like this in recent years in the hope of observing electromagnetic radiation (be it visible light, radio waves, X-rays or gamma-rays) from the events that trigger gravitational waves and send them rippling across the cosmos. Such an observation of electromagnetic radiation had never been made alongside a gravitational wave before but now, with GW170817, the LIGO-Virgo team worked with great urgency to notify their colleagues who had spotted the Gamma-ray burst.

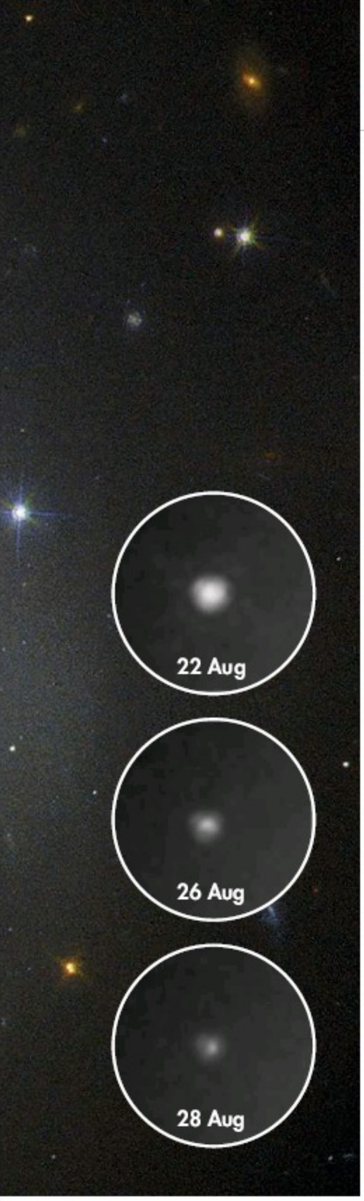
"We already knew that the Fermi team had circulated [news of the Gamma-rays] so everyone at LIGO worked hard to get [details of GW170817] out fast with as much accurate information as possible," says Agathos.

Using data from a third detector, Virgo in Italy, the researchers were able to narrow down the area of the sky that GW170817 had come from. "When we cross-checked our sky map with that of Fermi, which was relatively wide but still narrowed down the location to a few hundred square degrees, we noticed a significant overlap. That encouraged people to believe that this was something that may be picked up by other telescopes," says Agathos.

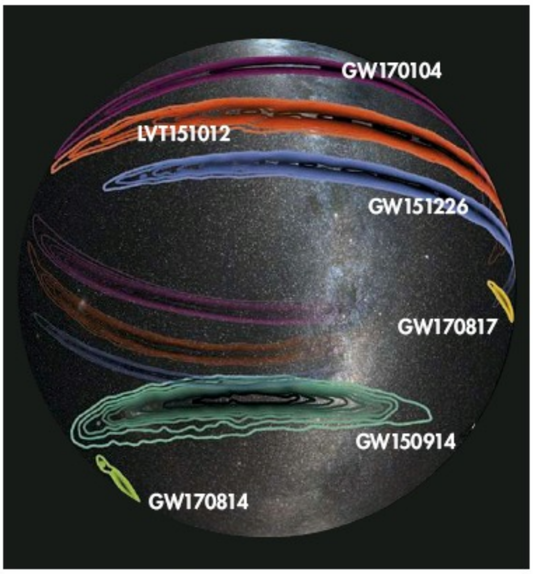
"For the very first time, researchers had caught both electromagnetic radiation and gravitational waves emanating from an astronomical phenomenon"

On the ground, the professional observatories in Chile slewed towards the area specified by the LIGO-Virgo team, picking out a new pinprick of light in NGC 4993, a galaxy around 130 million lightyears away. Meanwhile in orbit, both the Hubble Space Telescope and NASA's Swift satellite spotted it too, while the Chandra X-ray Observatory would later detect X-rays streaming from the same location. One estimate from the European Southern Observatory suggests that around 70 observatories saw the glowing dot that had appeared in the distant galaxy. More significant than the large number of eyes on the new spot of light, however, is what the diversity of observations constituted.

NASA AND ESA X 2, LIGO/VIRGO/NASA/LEO SINGER (MILKY WAY IMAGE: AXEL MELLINGER), NASA/JPL-CALTECH, CHANDRA X-RAY OBSERVATORY, LSC/ALEX NITZ, NASA/SWIFT



▲ Main image: it took just 12 hours for scientists to determine that the gravitational wave and gamma-ray burst had originated from the galaxy NGC 4993, where they also spotted an associated kilonova (circled). Inset images: the Hubble Space Telescope was able to observe the kilonova as it faded over the next few days



▲ Astronomers could narrow the origin of each wave detection to the coloured search area, but help from Virgo allowed them to pinpoint GW170817 more precisely

For the very first time, researchers had caught both electromagnetic radiation and gravitational waves emanating from an astronomical phenomenon. And with the data they'd amassed, the science of multi-messenger astronomy – of studying distant celestial objects by examining more than just the light they emit – took a vast leap forward.

As had long been hoped, decades of technological improvements had brought gravitational wave detection to the point where it could work in concert with all kinds of observatories to provide astronomers with a new way to scrutinise astrophysical processes. And nowhere was this better demonstrated than in the revelations that came from the analysis of the GW170817 event.

Looking beyond the wave

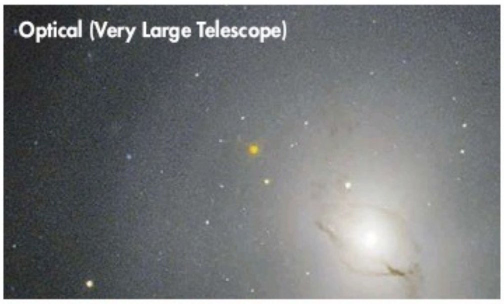
"The data that we see in [a] gravitational wave detection is in a waveform," says Agathos. "You can see it as a wave that evolves in a certain way and the structure of it gives you information about the source that generated it."

Analysis of the GW170817 gravitational wave suggested that the event which had produced it was a violent collision between two neutron stars that had been spiralling in towards each other. When the two stars finally collided, the force of the impact shuddered the fabric of space-time, sending the gravitational wave rippling across the cosmos. It also illuminated their host galaxy with a powerful blast of radiation – the light the world's telescopes picked up in August. ▸

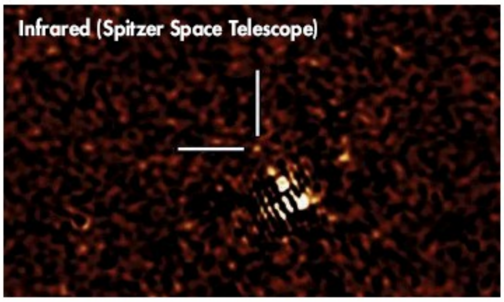
GW170817

a multi-messenger view

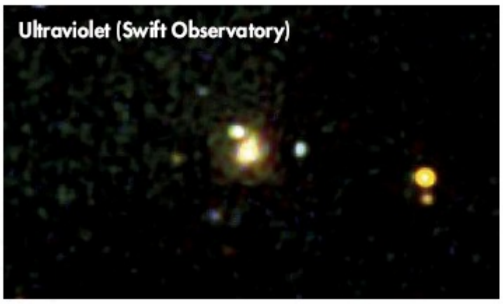
These images show how different observatories and telescopes saw the light from the neutron star merger of 17 August 2017, as well as a visualisation of the LIGO gravitational wave signal from the event.



Optical (Very Large Telescope)

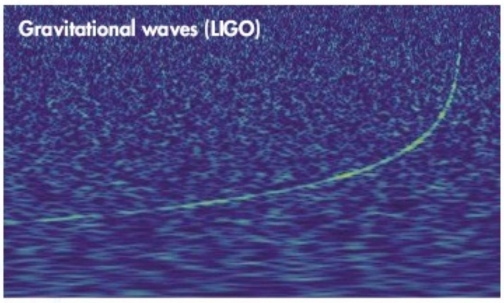


Infrared (Spitzer Space Telescope)



Ultraviolet (Swift Observatory)

X-ray (Chandra X-ray Observatory)



Gravitational waves (LIGO)

"This revelation from the study of GW170817 was the first triumph of multi-messenger astronomy, but it wasn't the only one"

▸ The identification of a neutron star binary system as the origin of GW170817 was important in itself. The initial flash that the Fermi telescope saw was a phenomenon known as a short gamma-ray burst. Short gamma-ray bursts had been observed many times prior to the GW170817 event and one of the theories that astronomers had put forward for what causes them was the merging of neutron stars.

With Fermi's observation of the short gamma-ray burst and a simultaneous detection of a gravitational wave produced by a collision of neutron stars, astronomers now had a key piece of evidence to support that theory.

The kilonova question

This revelation from the study of the GW170817 gravitational wave was the first triumph of multi-messenger astronomy, but it wasn't the only one. The telescopes observing the electromagnetic radiation from the explosion caused by the two neutron stars colliding were able to capture spectra of the event. In doing so they were able to shed light on one of the great enigmas in astrophysics: where some of the heaviest elements in the Universe come from.

"Once you have the spectrum you can infer things about the [chemical] composition of the matter that you're observing," says Agathos. "The fact that we saw spectral lines of certain elements in this detection indicated that a big portion of elements, such as gold, platinum, uranium or other heavy elements, [are] actually produced in this type of process. This had been an open question for decades."

Those heavy elements were flung out by the explosion observed by the follow-up telescopes – a powerful blast known as a 'kilonova', which astronomers had for many years suspected would occur when two neutron stars smash together. Kilonovae are fainter and release less material than supernovae, but as they dim rapidly they're much more tricky to catch.

Might we one day detect the gravitational waves that began at almost the same instant as the Big Bang itself?

NEW OPPORTUNITIES AWAIT

Neutron stars and kilonovae aren't the only things multi-messenger astronomy could help reveal

While astronomers eagerly await further multi-messenger observations of kilonovae and perhaps supernovae too, there are other fields of astrophysics and cosmology in which gravitational wave detections should provide extraordinary insights. Such studies will naturally build on and illuminate more fully decades', if not centuries', worth of understanding from electromagnetic radiation observations, but in some cases they will also explore astronomical phenomena that simply cannot be studied by examining light of any wavelength. Black hole mergers, which don't give off light and which LIGO has sensed several times already, are perhaps the most obvious example, but there are others.

"If our gravitational wave detectors get sensitive enough we may be able to detect signals from the very early Universe," says Dr Michalis Agathos. "The picture that we have of the very early Universe at the moment comes mainly from the Cosmic Microwave Background. This is basically the light that streamed freely from the earliest stage when the Universe became transparent to light, about 350,000 years after the Big Bang." Gravitational waves, however, were able to move unhindered through the opaque cosmos long before this. "If you do the calculation, you'll see that gravitational waves started travelling freely and unperturbed from the first billionth of a trillionth of a trillionth of a second after the Big Bang. This is a really amazing prospect: if you're able to detect gravitational waves from the very early Universe you'll basically probe the very beginning," says Agathos.

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▲ Neutrinos can travel vast distances without interacting with any matter, which makes them difficult to detect

▲ The few confirmed neutrinos that have been detected were picked up moments before the light from Supernova 1987A reached Earth

"Sometimes you can see objects that have characteristics which would have looked like the theoretical models put forward for a kilonova," says Dr Kate Maguire, an expert in supernovae from Queen's University, Belfast. "But because they fade away very quickly from their brightness we never had good datasets."

Indeed, the multi-messenger nature of the GW170817 observations was crucial to positively identifying it as the kilonova predicted by models. "This is the first object that's conclusively a kilonova, because we have the gravitational wave detection of the two neutron stars merging," adds Maguire.

More messages

Astronomers hope to make more multi-messenger observations of kilonovae in order to get a better understanding of these events. But future multi-messenger astronomy studies may also offer new insight into their more energetic cousins, supernovae, as well. And that's because there's another type of 'messenger' to pick up, a messenger that wasn't detected in the GW170817 event but one that could reveal the inner workings of these violent stellar detonations: neutrinos.

Neutrino particles can be produced in the powerful core-collapse supernovae that occur when a massive star dies, but they're extraordinarily hard to detect and require specialist detectors, such as the IceCube Neutrino observatory located at the South Pole. "We've only seen neutrinos from one supernova, 1987A, and that was 20 neutrinos out of [a theorised total of] 10^{58}," says Maguire.

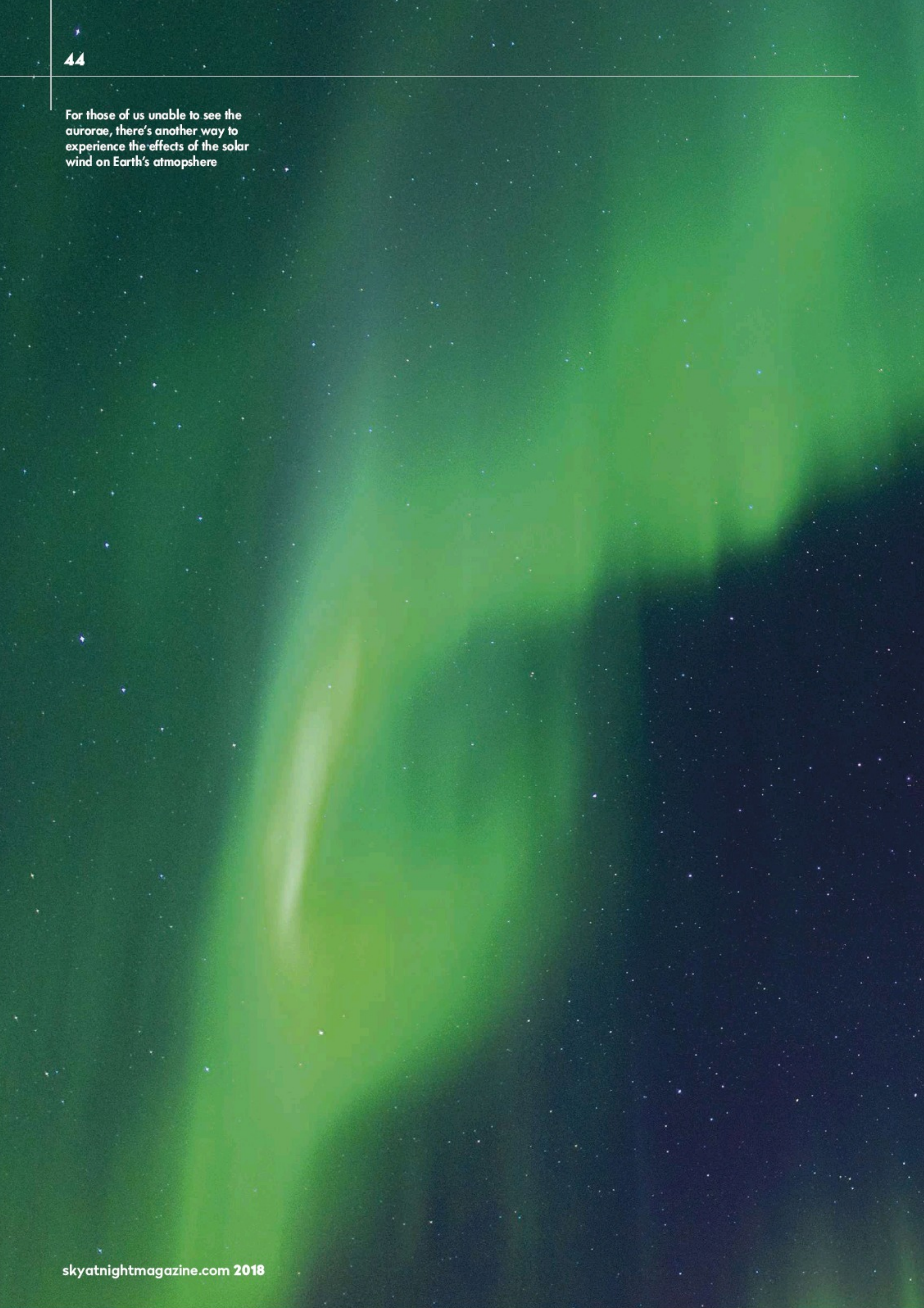
▼ A team of around 300 physicists search for neutrinos using the IceCube Observatory at the South Pole

Nevertheless if a supernova went off in the Milky Way and enough neutrinos could be detected from the blast, along with gravitational waves and electromagnetic radiation, it would be a pivotal observation. "The neutrinos would tell us about the explosion mechanism of the core-collapse supernova," explains Maguire. "The gravitational wave detection would be very nice for tying down the properties of the system, such as the mass. And we'd have the electromagnetic radiation as well – because it would be a supernova in our galaxy we'd be able to get very detailed observations. It would be incredibly exciting if we were able to do that."

With LIGO coming back online later this year, professional astronomers will be preparing to jump into action when another gravitational wave signal is detected. But there's another development on the horizon that should excite amateur astronomers too. In the future, the private notifications that the LIGO team send out to collaborators alerting them to a potential new gravitational wave event will be made more widely available.

"One cannot exclude the possibility that certain sources may be observable by amateur astronomers with decent telescopes," says Agathos. "For instance the host galaxy of the first neutron star binary [merger] detection was something in the region of [mag.] +12.4 and the source itself was not much dimmer. With a decent telescope, if you're lucky enough and you're in a place where the sky is dark and clear, you may actually be able to discover things before the large telescopes do."

The future of multi-messenger astronomy will certainly involve advanced, professional observatories and rapid-reaction, wide-field telescopes working alongside gravitational wave and neutrino detectors. But in among the authors of forthcoming studies they produce, we may well also see the names of dedicated amateurs working from their own back gardens.



For those of us unable to see the aurorae, there's another way to experience the effects of the solar wind on Earth's atmopshere

Measuring the aurora

Creating a homemade magnetometer allowed **Stuart Green** to keep a record of space weather, despite cloud and his southerly location

ABOUT THE WRITER

A composite materials engineer, Dr Stuart Green is a keen solar astronomer and space weather enthusiast

Earth is bathed in a constant stream of energetic particles originating at the Sun. This solar wind ebbs and flows, and occasionally explodes in a coronal mass ejection, throwing billions of tonnes of our star's plasma into space, which impacts on Earth's magnetosphere – our protective magnetic bubble. The result is bright and beautiful aurorae, the luminous splendour of which is our only visual confirmation of this Earth-Sun connection. For those fortunate enough to witness this spectacle, the lasting impression is one of awe at its magnificence. For the rest of us, such events are lost save for the images available online, through which we can only experience the aurorae vicariously.

A few years ago I was looking for a way to establish a degree of connectivity with the Sun that was otherwise unavailable to me in my lower latitude location in the UK. That's when I thought about building a magnetometer. Not only does the solar wind create the aurora, but in the process of being deflected by our protective magnetosphere, it also imprints its signature upon our protective bubble. This is detectable at any point on our planet with a magnetometer, which picks up the magnetic signature as it fluctuates according to the strength, speed and magnetic orientation of the passing plasma.

Magnetometers can be purchased commercially, of course, but my interest lay in building one for the fun of it and for the challenge. The basic scheme of the design is a highly sensitive magnetic sensor, an ultrasonic emitter, an ultrasonic-to-audio frequency converter and a computer with a sound card and Spectrum Lab audio spectrum analysis software for data logging.

A stable environment

At the heart of this setup is the magnetic sensor. Called a fluxgate, these sensors can be extremely sensitive and are perfectly suited to measuring the tiny perturbations in the local magnetic field caused by space weather. The particular sensor I used provides an output frequency that varies according to the strength of the magnetic field.

As well as responding to the magnetic field, the output frequency also changes with temperature, so the sensor has to be located in a temperature-stable environment. My sensor is buried in my garden about 0.5m below the surface. It is also protected by a waterproof housing made from 40mm diameter plumbing pipe fitted with end caps sealed using suitable solvent.

The sensor is positioned almost perfectly level on a poured concrete base and points along Earth's magnetic east-west direction. It's also sited away from any stray magnetic fields that might be created by local electric cables and equipment. The fluxgate sensor's power supply also has to be stable to avoid spurious readings, so mine is linked to a ▸

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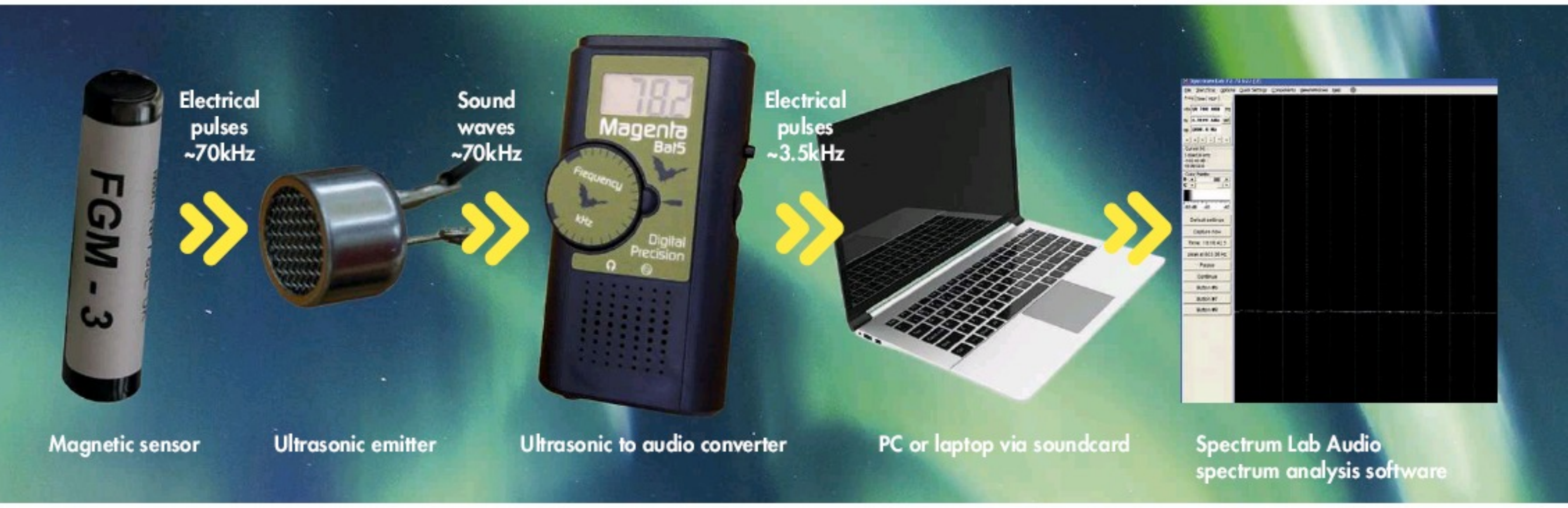

FGM - 3
Electrical pulses ~70kHz
Sound waves ~70kHz
Magenta Bat5
Frequency
kHz
Digital Precision
Electrical pulses ~3.5kHz
Magnetic sensor
Ultrasonic emitter
Ultrasonic to audio converter
PC or laptop via soundcard
Spectrum Lab Audio spectrum analysis software

▲ The magnetometer is made up of a magnetic sensor in a protective housing, an ultrasonic emitter, an ultrasonic to audio frequency converter (the bat detector) and a computer to capture, record and display the data using free spectrum analysis software

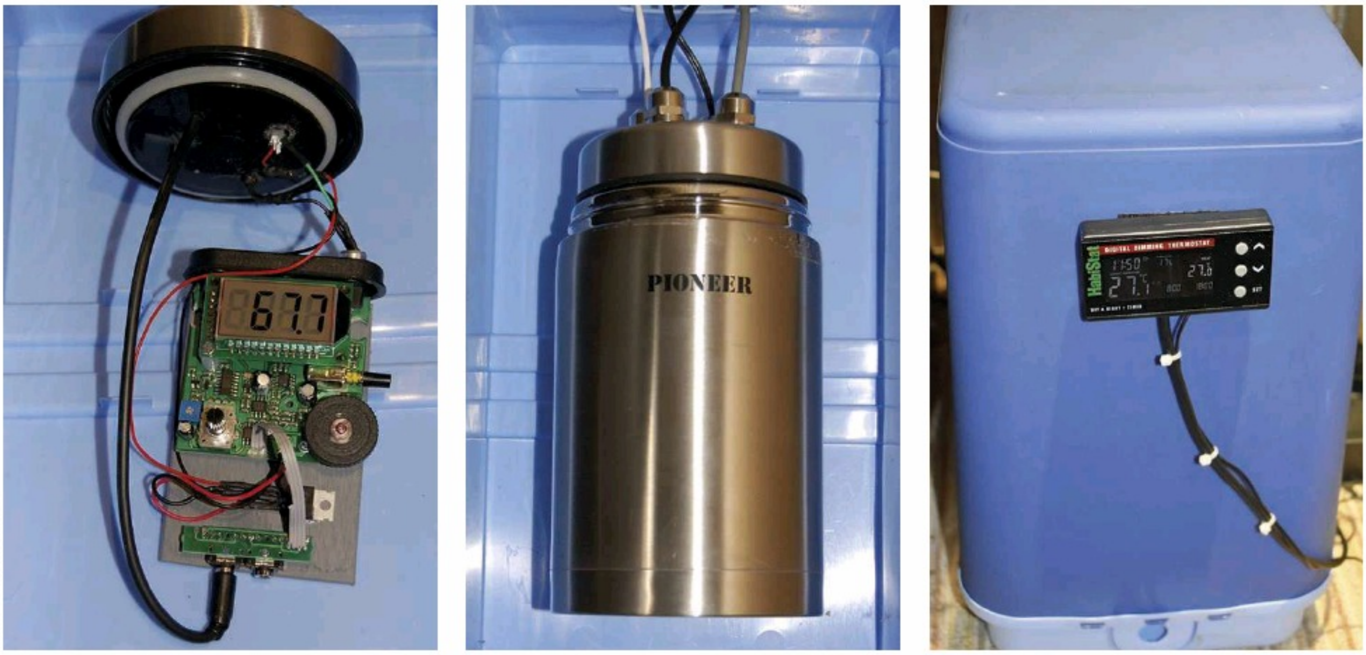
▸ linear voltage regulator that converts 9V DC from a mains transformer to a stable 5V DC supply.

When pointing east-west, the output from the fluxgate sensor is a train of +5V square wave pulses at a frequency in the range of 60-70kHz, which is significantly above the operating frequency of any standard computer sound card. So I turned to equipment intended for zoology and connected the output of the magnetic sensor to a bat detector with an ultrasonic transducer emitter.

Bat detectors are designed to convert ultrasonic bat calls into audio frequencies that we can hear. Commonly this is accomplished by a process called heterodyning, in which an internally generated, tuneable reference frequency is mixed with the varying ultrasonic input signal from the bat to create audible sound at a frequency equal to the difference between input and reference frequencies.

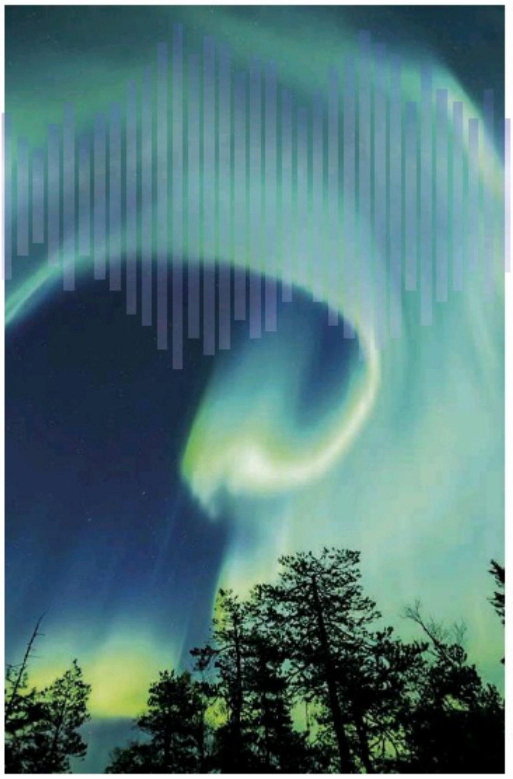
Frequency range

For the purposes of magnetometry, this frequency difference should be tuned to a single audible tone that can be recorded with a standard computer sound card. I found 3-4kHz to be a suitable range. The other advantage of using a bat detector is that the audio output is of good fidelity, meaning that subsequent data analysis can be accomplished at high resolution. For this project, I used a detector



▲ Temperature stability is vital, hence the magnetometer (left) is housed in a vaccuum flask (centre), which is kept inside cool box (right)

STUART GREEN X 7, ISTOCK X 4



The sound of space weather

Once the data from the solar wind hitting Earth's magnetosphere has been collected, it's possible to create an audio file from it

Taking things a step further with an online algorithm, it's possible to convert the output magnetic field strength data into sounds using the MIDI (Musical Instrument Digital Interface) protocol. In this process, each field strength value is converted to a MIDI value representing a particular musical note, which is then fed into music production software to prepare an audio track.

MIDI allows any digitised instrument to be assigned to play the note, although my preference is to use a synthesised wind sound to represent the solar wind. In reality, the data relate directly to local magnetism, not to the solar wind, yet to hear the sounds generated by such a method is evocative as one imagines the stream of particles pushing against our protective magnetic field, occasionally entering to create the ethereal aurora.

Once the magnetic declination data generated by my magnetometer was sonified, it could be synchronised with a timelapse video of the aurora borealis to create an audio-visual experience similar to this one: bit.ly/2n9ohFo. The correlation between the video, created by Kai-Maeius Pederson in Tromsø, Norway, and the audio is not perfect – probably because of the physical separation between it at the sound recording in the UK – but there is a satisfying degree nevertheless. More sonified geomagnetic data can be found at bit.ly/2n9rHc1.

> "I now have that connection with the cosmos that I was looking for, with data streaming into my PC constantly, capturing the ebb and flow of the solar wind"

with an internal crystal oscillator for precision and to minimise any frequency drift. This detector is usually powered by a set of batteries, but as that only provided a battery life of less than 24hrs, the batteries were swapped for another stabilised DC feed from the 9V mains transformer.

Gathering data

With the detector set up I was ready to log data, and for this I used free software called Spectrum Lab, written by Wolfgang Buescher (www.qsl.net/dl4yhf/spectral.html). This enables the data stream to be displayed as a continuous chart as the day progresses. The software can also send measured frequency data to a computer hard drive at preselected intervals, together with a time and date stamp, building up a database throughout an entire geomagnetic event. Later, this database can be exported as a CSV file and copied into an Excel spreadsheet for further analysis. Any time period between logged events can be selected; I use a one-second cadence for high resolution work and a 150-second cadence for standard resolution work.

Analysing the data involves converting frequency to magnetic field strength (more accurately magnetic flux density in nano-Tesla) using conversion factors provided by the sensor manufacturer, and then charting the result as a function of time.

As it turned out, my magnetometer needed a few refinements to make it more consistent with professional data, in particular better temperature control of the bat detector. The output from the detector was being significantly impacted by small ambient temperature fluctuations that were imprinting on the output frequency. It was only when the detector was placed in a temperature-defined environment (inside a vacuum flask, inside a cool box fitted with a vivarium heater mat at a controlled temperature) that the output met the professional readings.

The output from such a relatively simple device is remarkably consistent with data generated by professional geomagnetic monitoring stations such as Eskdalemuir, operated by the British Geological Survey, and its sensitivity and resolution certainly compete favourably for the hobbyist with the output from magnetometers costing considerably more.

Having established my homemade magnetometer I now have that connection with the cosmos that I was looking for, with data streaming into my PC constantly, capturing the ebb and flow of the solar wind and occasional coronal mass ejection that buffets our planet. **S**

YOUR BONUS CONTENT

Print out a pdf with further details about this project and schematic diagrams

1000 photos without electricity – our first fully automatic mechanical mini-mount

NEW

For successful amazingly beautiful star field shots that anyone can take.

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The Big Dipper & Calascio Rock – Photo: Cristian Fattinnanzi

ISN'T THIS ASTRONOMY PHOTO AMAZING?

Using the Omegon MiniTrack LX2 mount, you too can successfully take such wide-field photos. This fully mechanical mount works using clockwork alone. No electricity, no charging and no batteries are required. Just put the mount onto a tripod, attach your camera, and wind it up. You are then free to take beautiful wide-field images of the night sky with your camera.

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PLUS

Stephen Tonkin's
BINOCULAR TOUR
Turn to page 60 for six of this month's best binocular sights

Written by
PETE LAWRENCE
Pete Lawrence is an expert astronomer and astrophotograper, and a presenter of *The Sky at Night* on BBC Four.

The SKY GUIDE March

There's an opportunity to watch the occultation of two bright stars this month as the Moon passes in front of Regulus and Aldebaran

PETE LAWRENCE

DON'T MISS...

- ▷ Two close conjunctions of Venus and Mercury
- ▷ Lunar occultation of the Hyades
- ▷ The Zodiacal Light

MARCH HIGHLIGHTS

Your guide to the night sky this month

THURSDAY

1

Regulus (Alpha (α) Leonis) is occulted by the virtually full Moon at 06:06 UT from the centre of the UK. Reappearance occurs after the Moon and Regulus have set.

FRIDAY

2

The full Moon that occurs at 00:52 UT this morning is the first of two that will occur in March.

SUNDAY

4

Mercury appears 1.1° from Venus in the evening sky. Mag. –3.8 Venus acts as a beacon to locate Mercury, but the Solar System's innermost planet stands its ground against the evening twilight too, shining away at mag. –1.1.

SUNDAY

11

Catch the 34% waning crescent Moon rising just after 04:00 UT and you should be able to spot mag. +0.9 Saturn a little under 2° below and to the southwest of it.

TUESDAY

13

With no moonlight to interfere, the next few evenings are a great time to take our tricky challenge on page 61. This month we're looking for the subtle cone-shaped glow known as the Zodiacal Light.

THURSDAY

15

Evening planet Mercury reaches greatest eastern elongation today when it will appear to be separated from the Sun by 18.4°.

SUNDAY

18

Mag. –3.8 Venus, +0.4 Mercury and a slender 1%-lit waxing crescent Moon form a straight line low in the west after sunset. Venus should be easy to spot: Mercury is 3.8° above and to the right of it, while the Moon is 4.5° below and to the left.

MONDAY ▶

19

Mars is currently located between the Lagoon Nebula, M8, and the Trifid Nebula, M20. It should be possible to spot this arrangement from around 03:30 UT. Mag. +0.5 Mars will appear low in the southeast at this time.

◀ TUESDAY

20

The centre of the Sun crosses the celestial equator at 16:15 UT, passing from the southern to the northern celestial hemisphere. This is a point in time known as the Northern Hemisphere's spring, or Vernal, equinox.

FAMILY STARGAZING – 1, 22 MAR

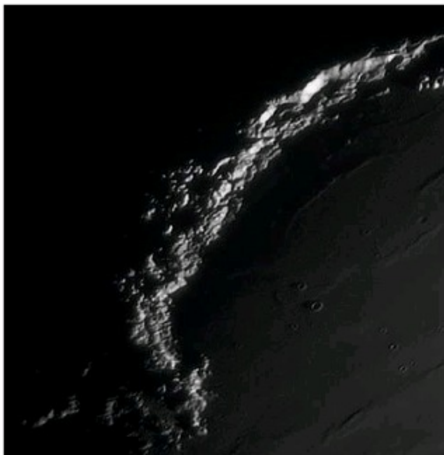
There are two lunar occultations of bright stars this month. These are exciting to watch and great fun to observe: see page 52 for timings. The occultation of Regulus on 1 March requires an early start while that of Aldebaran happens around midnight on 22 March. Binoculars or a telescope fitted with a low-power eyepiece are great ways to watch bright star occultations. Even with these instruments, make sure you keep your eyes peeled though, because the actual disappearance happens in the blink of an eye!

www.bbc.co.uk/cbeebies/shows/stargazing

TUESDAY ▶

27

It should be possible to see the clair-obscur effect known as the Jewelled Handle on the Moon this morning. Conditions are ideal around 01:00 BST (00:00 UT). The effect occurs when the tops of the Montes Jura around Sinus Iridum catch the morning Sun.

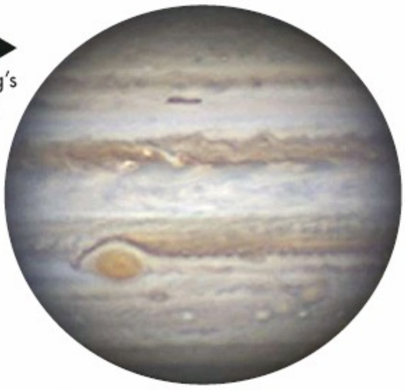


PETE LAWRENCE X 9

WEDNESDAY ▶

7

This morning's 71% waning gibbous Moon lies 4.75° north of mag. –2.1 Jupiter. Both objects are located in the constellation of Libra at this time and can be seen due south at 04:30 UT.



SATURDAY

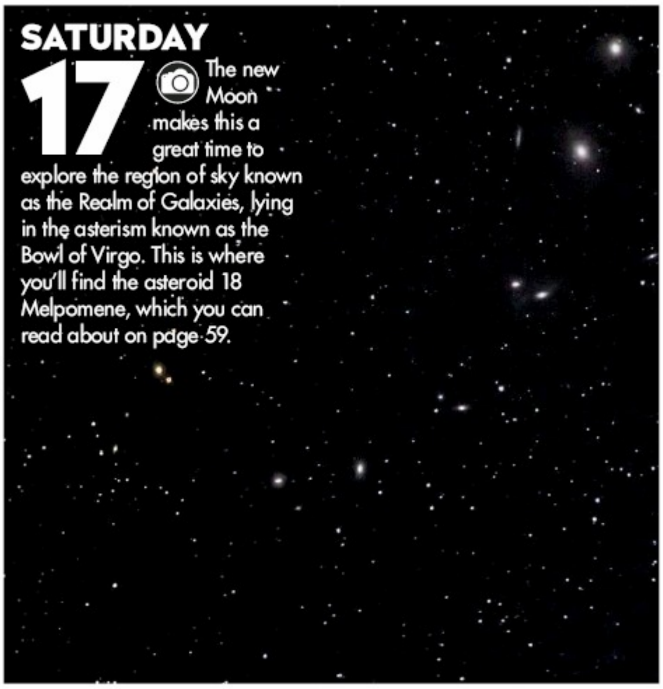
10

Today, it's the turn of mag. +0.7 Mars to be close to the Moon. Spot the Red Planet and the 43% waning crescent Moon 3.5° apart shortly after rising, low in the southeast just after 03:00 UT.

FRIDAY

16

With the Moon absent in the night sky, this is a great time to try for our Deep Sky Tour targets listed on page 63. This month, we're taking a look at objects in the eastern part of Canes Ventatici.



SATURDAY

17

The new Moon makes this a great time to explore the region of sky known as the Realm of Galaxies, lying in the asterism known as the Bowl of Virgo. This is where you'll find the asteroid 18 Melpomene, which you can read about on page 59.

◀ THURSDAY

22

The 29%-lit Moon moves through the Hyades open cluster after sunset, passing north of the V-shape's southern arm. Occulted stars include Aldebaran, which vanishes after 23:30 UT and reappears at 00:15 UT on 23 March.

SATURDAY

24

Locate the Moon with a telescope at around 17:00 UT and see if you can spot the ray across the floor of crater Barrow. A daylight sky will make things a little harder, but it should still be possible to see the effect.

SUNDAY

25

At 01:00 UT this morning the clocks go forward by one hour, marking the start of British Summer Time in the UK.

SATURDAY ▶

31

Like January this year, March has two full Moons and the second occurs today. Although not the original meaning of the term, the second full Moon in a month is known as a Blue Moon.

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY
Objects marked with this icon are perfect for showing to children

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

BINOCULARS
10x50 recommended

SMALL/ MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

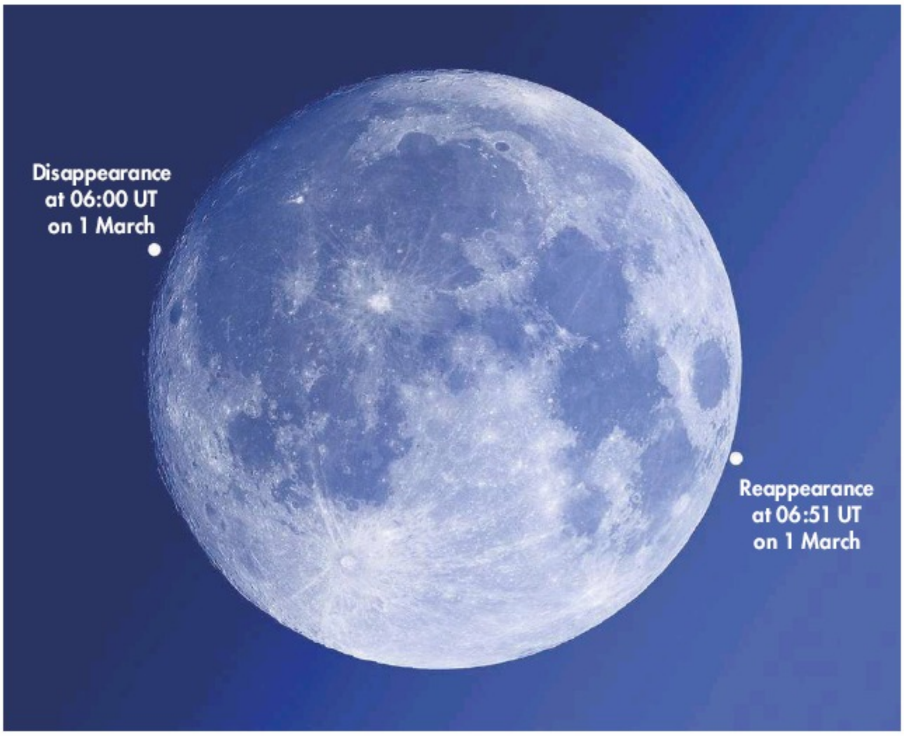
THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

Lunar occultations

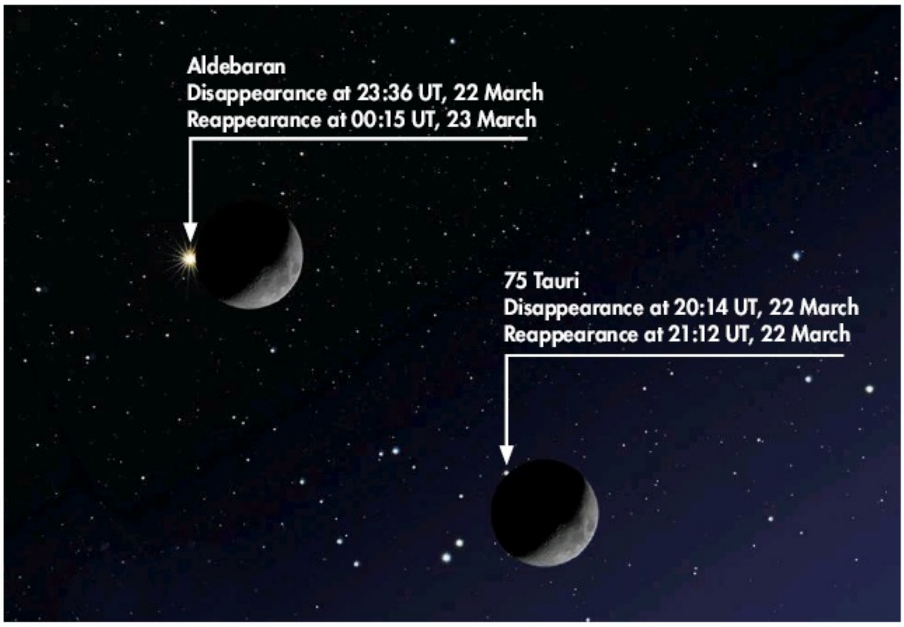
WHEN: 15 minutes prior to occultation times mentioned


Disappearance at 06:00 UT on 1 March
Reappearance at 06:51 UT on 1 March

▲ The Moon's phase at the time of the occultation: 99% waxing; Regulus's appearance has been exaggerated for clarity. Times correct for the centre of the UK

The Moon presents a disc with an apparent diameter of half a degree. Despite how large it looks in your mind's eye, this disc is actually quite small. As an example, look to the west after the sky darkens, where you'll find the Pleiades open cluster. If you're not sure how to identify this, extend the line of Orion's Belt to the right. Keep going past the bright orange star Aldebaran and eventually the line brings you to the Pleiades. Two full Moons would fit side-by-side across the longest dimension of this cluster.

The Moon occults two bright stars this month. The first occurs on the morning of 1 March when the virtually full Moon closes in on mag. +1.3 Regulus (Alpha (α) Leonis). It reaches the star with the dawn twilight well under way and despite the brightening sky, the disappearance at 06:00 UT should be fairly easy to observe. The reappearance at 06:51 UT is another matter altogether. Apart from the fact that both the Moon and Regulus will be approaching the west-northwest horizon at this time, the Sun will also be about to rise. Regulus can be seen in daylight but being low down in the sky may make spotting the reappearance challenging.


Aldebaran
Disappearance at 23:36 UT, 22 March
Reappearance at 00:15 UT, 23 March
75 Tauri
Disappearance at 20:14 UT, 22 March
Reappearance at 21:12 UT, 22 March

▲ The Moon's phase varies from a 29% to 31% waxing crescent as it passes through the Hyades

PETE LAWRENCE X 4

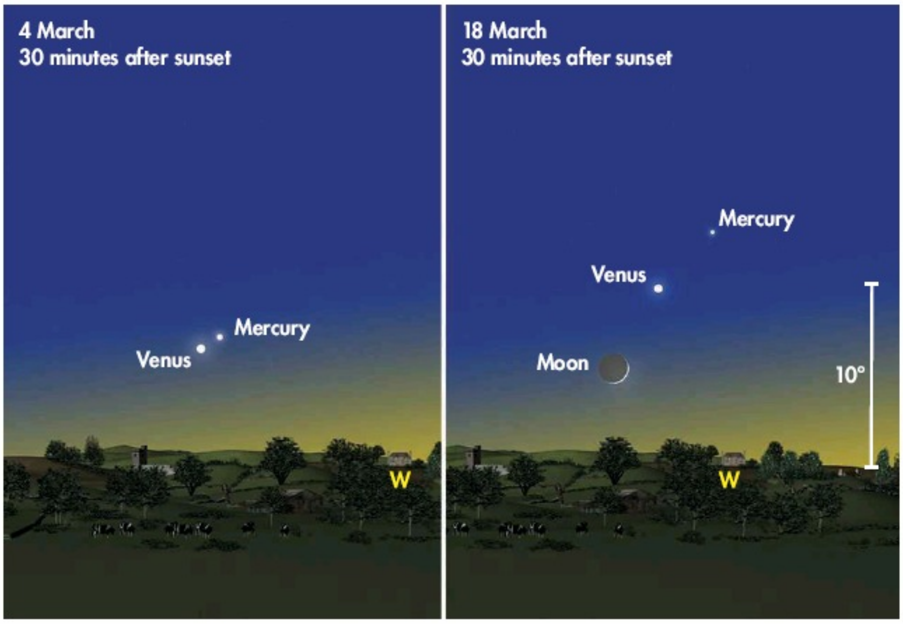
The second occurs on the night of 22 March: locate the crescent Moon in the west-southwest as darkness falls. It should be passing through the Hyades open cluster at this time. You'd think that this would result in some spectacular occultations but the Moon's relatively small disc is able to pass surprisingly well between the brighter stars.

The first naked-eye Hyad to disappear will be mag. +4.9, 75 Tauri, which from the centre of the UK will vanish behind the Moon's dark limb at 20:14 UT. As ever with lunar occultations, the timing will differ depending on location, so observe at least 15 minutes before the stated event time to ensure you don't miss anything. Reappearance from the bright limb occurs almost an hour later at 21:12 UT.

The Moon manages to avoid most of the other bright stars in the southern part of the Hyades, but there are plenty of events involving the fainter members. At 23:36 UT, mag. +0.8 Aldebaran (Alpha (α) Tauri) disappears behind the Moon's dark limb. It reappears at 00:15 UT. As with Regulus, the reappearance event occurs when the Moon and Aldebaran are close to setting, so make sure you have a good flat west-northwest horizon if you intend to observe it.

Mercury, Venus and the Moon

WHEN: Dates and times as stated



▲ Mercury approaches and retreats from Venus before the two planets part ways during March

Mercury and Venus dance with one another in the evening sky this month. Things get off to an exciting start with both planets separated by less than 2° on the night of 1 March. On this date you should be able to see them 30 minutes after sunset, 5° above a flat western horizon.

Venus should be easy to spot as it'll be really bright at magnitude –3.8, easily able to cut through the bright evening twilight. Mercury is dimmer but at mag. –1.2 it should still be easy to see as long as the atmosphere is clear low down.

The separation decreases over the next couple of evenings, being 1.4° on 2 March and 1.1° on 3 and 4 March. After that the two planets appear to separate, with Mercury appearing to move higher above Venus. This process doesn't last, however, because Mercury's smaller orbit caps its range and by 15 March, when it reaches its greatest eastern elongation of 18.4°, its relative climb above its Solar System neighbour comes to a halt.

After 15 March, Mercury slips back toward the Sun, while Venus continues its slow crawl in the opposite direction. A second, albeit wider, close encounter occurs on 18 and 19 March. On 18 March, Venus and Mercury appear separated by 3.8° with a very thin, 1% waxing lunar crescent close by. This will appear roughly in line with the planets.

On 19 March the 5%-illuminated Moon will have moved further east, with the planets still 3.8° apart. This distance begins to grow steadily larger over the following evenings.

The brightness of Venus remains steady over this period but Mercury dims. On 18 March, Mercury shines at mag. +0.4, dimming to +0.7 by the 19th. By the end of the month, Mercury is lost from view, Venus taking up the mantle as a beacon of the evening sky.

Blue Moon II

WHEN: Nights of 2 and 31 March

After having two full Moons in January, there are two full Moons this month too, one on the 2nd and one on the 31st. Moon phases repeat in a period known as a synodic, or lunar, month, which is approximately 29.5 days long. If a full Moon occurs early enough in a month with at least 30 days, it's possible to fit two full Moons in before the month expires.

The second full Moon in a month is known as a Blue Moon, despite the fact that nothing about the Moon will be blue. The term Blue Moon originated in the *Farmer's Almanac* in which the usual three full Moons that occurred per season all had names. But the differences between the synodic and calendar months meant that every so often a fourth full Moon would creep into a season, messing up the naming convention. This extra Moon was referred to as a Blue Moon to keep everything in phase.

A misinterpretation of this original meaning described how the second full Moon in a calendar month was called a Blue Moon. Despite the mistake, this definition stuck and is now frequently used to describe such an occurrence. The last time that there were Blue Moons in January and March was in 1999 and this occurs approximately four times every century.

▲ The second Blue Moon of the year appears at the end of March, but its colourful name is not an accurate description of its appearance

THE NORTHERN HEMISPHERE
IN MARCH

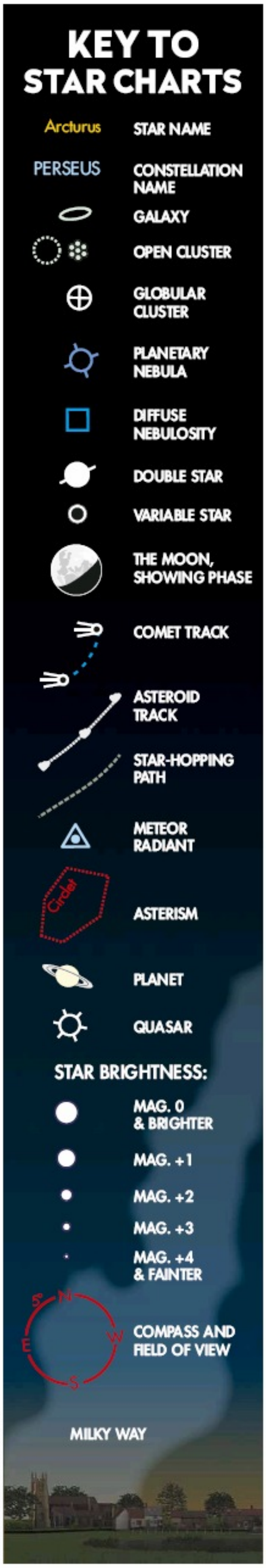


CHART: PETE LAWRENCE

WHEN TO USE THIS CHART

1 MAR AT 00:00 UT
15 MAR AT 23:00 UT
31 MAR AT 23:00 BST

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN MARCH*

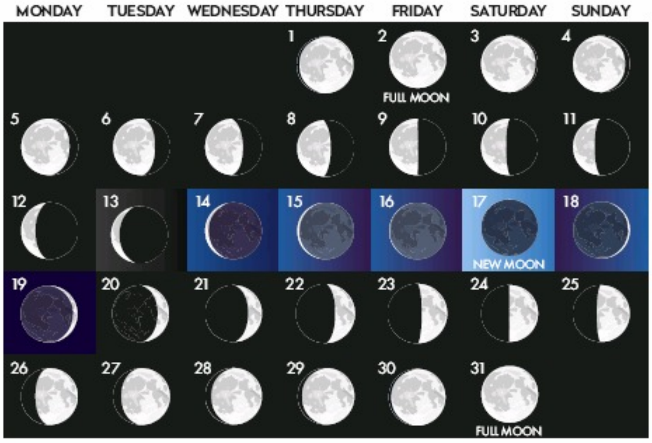
DATE	SUNRISE	SUNSET
1 Mar 2018	06:58 UT	17:48 UT
11 Mar 2018	06:35 UT	18:07 UT
21 Mar 2018	06:10 UT	18:25 UT
31 Mar 2018	06:46 BST	19:43 BST

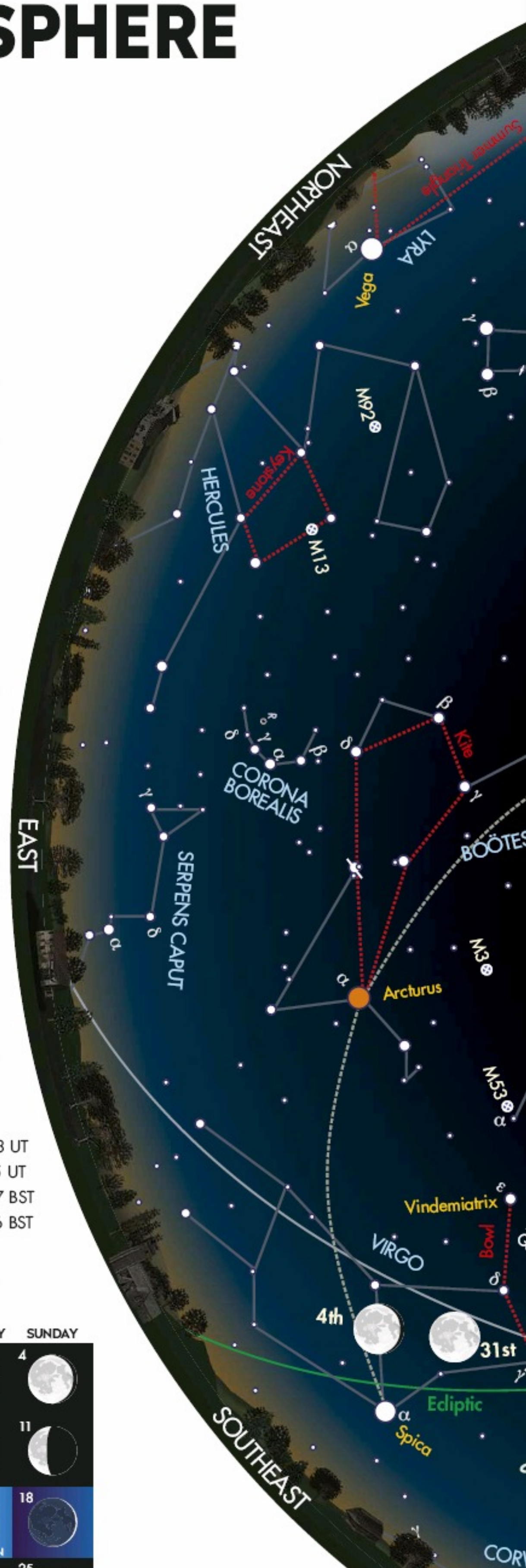
MOONRISE IN MARCH*

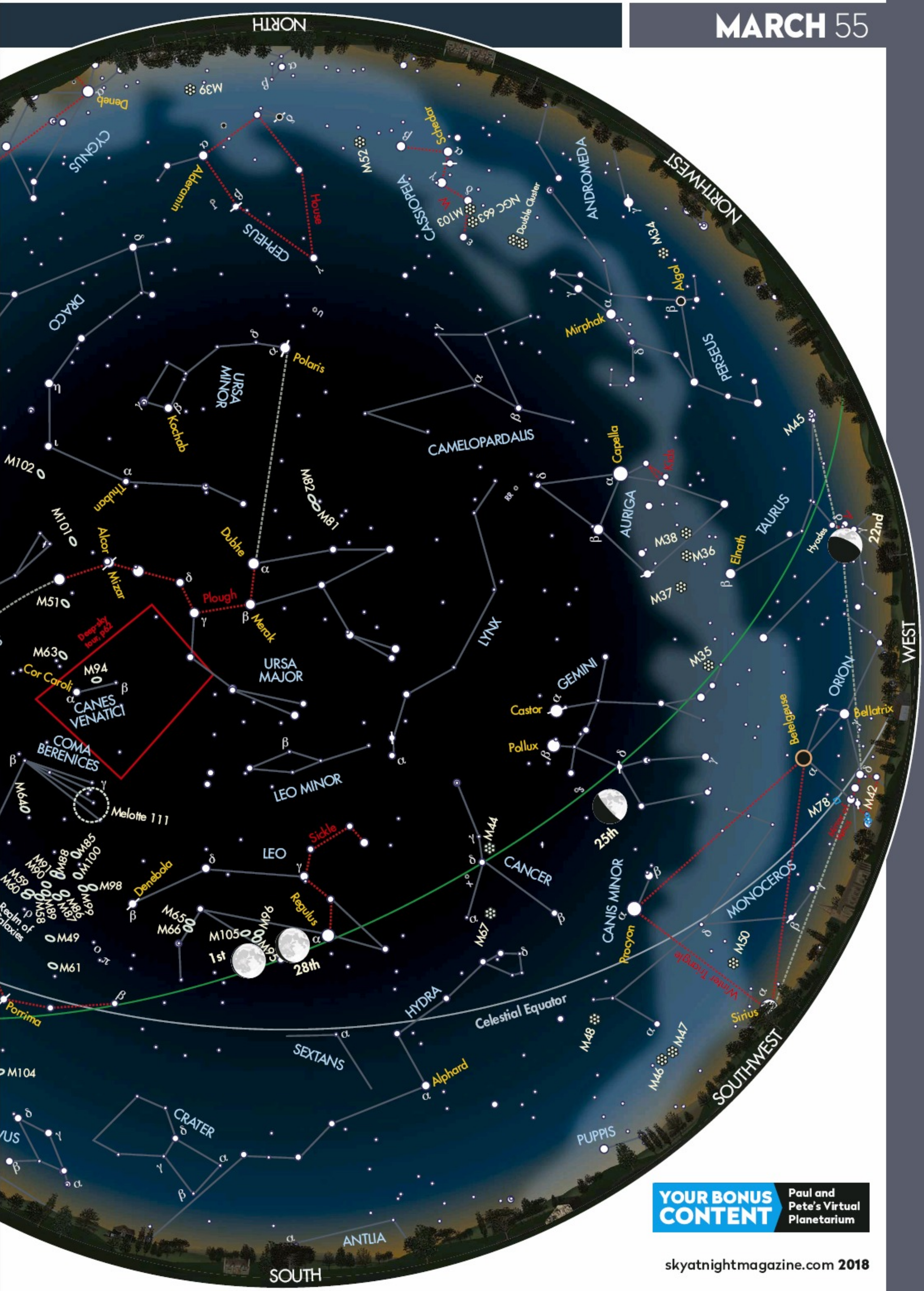
MOONRISE TIMES	
1 Mar 2018, 17:10 UT	17 Mar 2018, 06:43 UT
5 Mar 2018, 22:19 UT	21 Mar 2018, 08:15 UT
9 Mar 2018, 01:41 UT	25 Mar 2018, 12:07 BST
13 Mar 2018, 04:49 UT	29 Mar 2018, 17:06 BST

*Times correct for the centre of the UK

LUNAR PHASES IN MARCH







YOUR BONUS CONTENT Paul and Pete's Virtual Planetarium

THE PLANETS

PICK OF THE MONTH

MERCURY

BEST TIME TO SEE: 15 March, 18:50 UT
ALTITUDE: 11°
LOCATION: Pisces
DIRECTION: West
FEATURES: Phase, subtle markings
EQUIPMENT: 75mm or larger

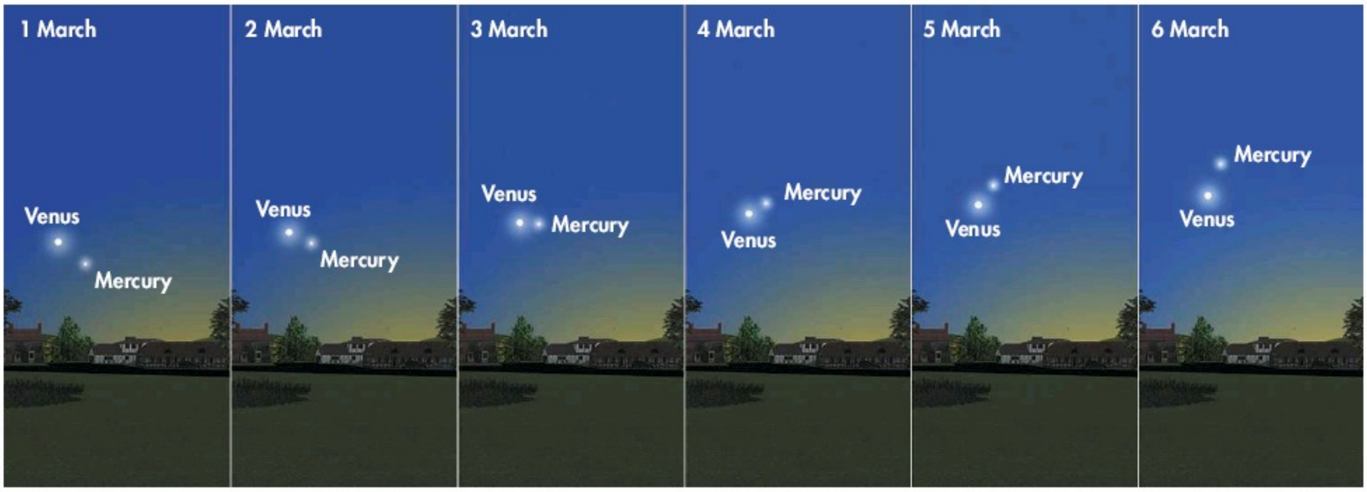
Mercury has a close encounter with dazzling Venus in the evening sky on 3 March as it moves toward a very favourable eastern elongation mid-month. Both planets appear separated by just over 1° on 3 and 4 March, with mag. –3.8 Venus outshining its inner neighbour with ease.

Mercury is bright though, shining at mag. –1.1. Greatest eastern elongation occurs on 15 March when Mercury, now at mag. –0.1, sets nearly two hours after the Sun. This means it'll be visible against reasonably dark skies with Venus remaining nearby. On 18 March, mag. +0.4 Mercury, mag. –3.8 Venus and a 1%-lit waxing crescent Moon form a line in the sky, with Mercury at the top and the Moon at the bottom.

This is a great time to try and get a telescopic view of Mercury as its phase is now decreasing. On the evening of the 18th, the planet can be seen as an 8 arcsecond-diameter crescent, 31%-lit. Typically, and despite its favourable location, Mercury's light has to pass through a turbulent layer of atmosphere close to the horizon. Consequently, this small crescent often suffers from the wobbles and looks quite distorted.

Venus and Mercury jostle for position as the highest evening planet over the following days, Venus eventually winning the crown during the last week of the month. Mercury also begins to fade but remains nicely visible thanks to its extremely favourable location with respect to the Sun. On 23 March it appears as a mag. +1.8 dot 6° to the lower right of Venus. A telescope will show it as a slender 13%-lit crescent, 9 arcseconds across on this date. After the 23rd, Mercury moves ever closer to the Sun at an increasing rate ahead of it reaching inferior conjunction early next month.

▲ Mercury becomes visible in the early evenings during March

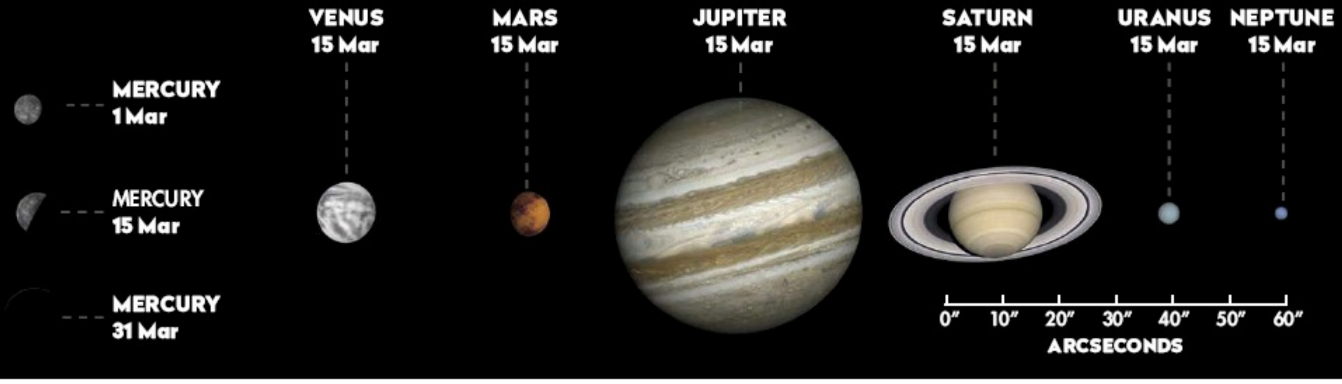


PETE LAWRENCE X 3

▲ Mercury and Venus appear approximately 20 minutes after sunset on the dates shown and remain in close proximity during the month

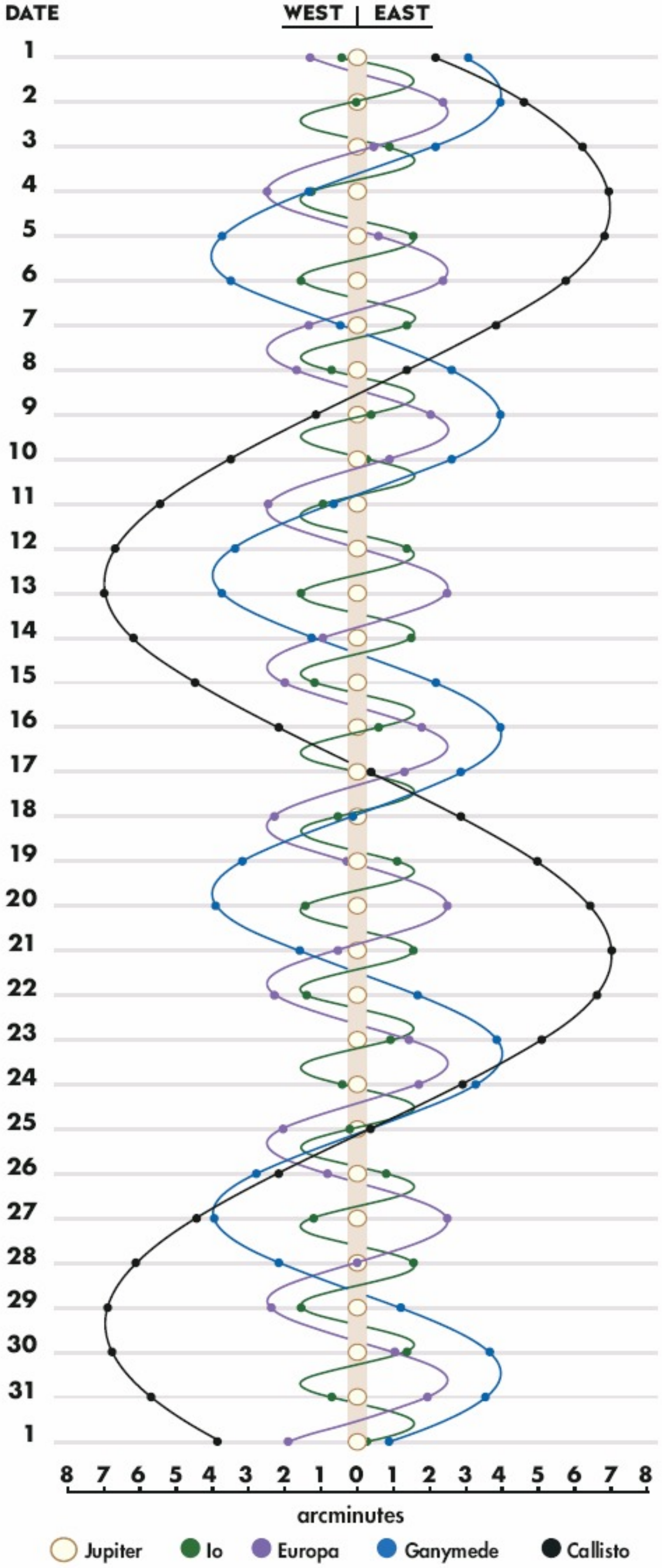
THE PLANETS IN MARCH

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



JUPITER'S MOONS MARCH

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



VENUS

BEST TIME TO SEE: 28 March, 30 minutes after sunset
ALTITUDE: 5° (low)
LOCATION: Capricornus
DIRECTION: West

Venus is an evening object that has a close call from Mercury between 3-5 March, the planets appearing just over 1° apart. Venus at mag. –3.8 outshines mag. –1.1 Mercury but both will be bright and obvious in the evening twilight, towards the west. Venus sets 90 minutes after the Sun mid-month. If you have a clear sky on the evening of 18 March, don't miss the sight of mag. +0.4 Mercury, –3.8 Venus and a 1%-lit waxing crescent Moon forming a celestial line. Look for them approximately 30 minutes after sunset. Venus should be visible first, then Mercury above and to the right with the Moon below and to the left of Venus. By the end of the month, Venus will set nearly two hours after the Sun. A telescopic view of the planet will show it to have a small 10 arcsecond disc 94%-illuminated on 31 March.

MARS

BEST TIME TO SEE: 31 March, from 04:00 UT
ALTITUDE: 9° (low)
LOCATION: Sagittarius
DIRECTION: South-southeast

Mars is a morning object moving east at the start of March, passing from Ophiuchus into Sagittarius. A 42%-lit waning crescent Moon is close on the morning of 10 March. On 18-20 March, mag. +0.5 Mars slips between M8, the Lagoon Nebula, and M20, the Trifid Nebula. If you want to catch this at its best, view the area from 03:45 UT onwards. By the end of the month, Mars will have brightened to mag. +0.3 and appears close to Saturn, both in Sagittarius. Telescopically, Mars is changing as it starts to approach Earth. On 1 March the planet shows a 5 arcsecond disc. By 31 March this increases to 8 arcseconds.

JUPITER

BEST TIME TO SEE: 31 March, 03:00 UT
ALTITUDE: 20°
LOCATION: Libra
DIRECTION: South

Jupiter is a mag. –2.0 morning object at the start of March with a 71%-lit waning gibbous Moon nearby on 7 March. At the end of the month, Jupiter brightens to mag. –2.2. Through a telescope Jupiter is 38 arcseconds across on 1 March, but grows to 42 arcseonds by 31 March.

SATURN

BEST TIME TO SEE: 31 March, 03:30 UT
ALTITUDE: 7° (low)
LOCATION: Sagittarius
DIRECTION: Southeast

Saturn is in Sagittarius, north of the Teapot asterism. It shines at mag. +1.0 with a yellowish hue. A morning object, it's best seen near the end of March. A lovely 34%-lit, waning crescent Moon lies 2° from the planet as they rise on the morning of 11 March. Look for them just before 04:00 UT, low in the southeast.

URANUS

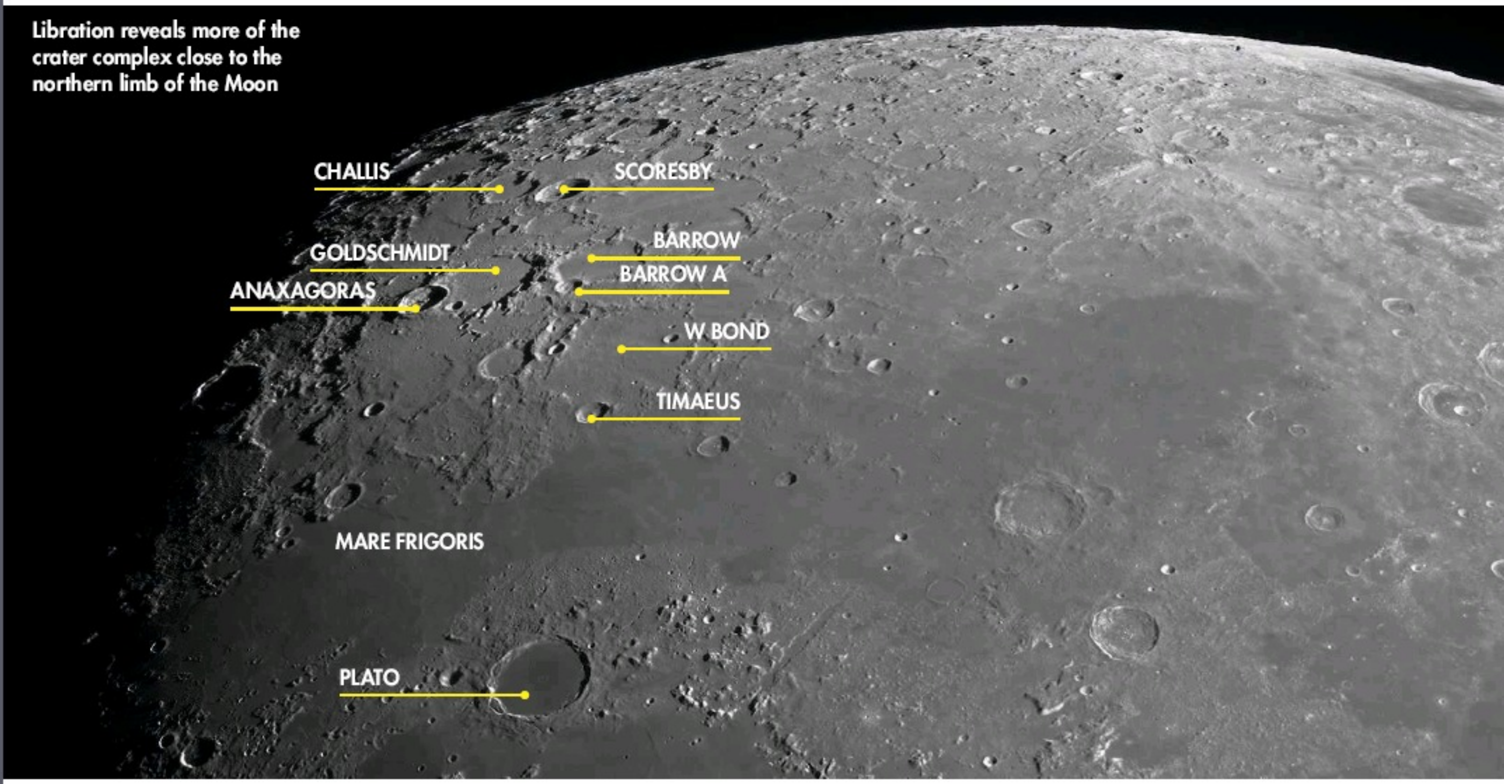
BEST TIME TO SEE: 1 March, 20:00 UT
ALTITUDE: 19°
LOCATION: Pisces
DIRECTION: West

Uranus is losing viability as an observing target. It's in Pisces and visible in the evening sky at the start of the month. But it's only visible when the planet is low in the west. A delicate 5%-lit waxing crescent Moon sits 5° southeast of Uranus on 19 March. If you can find Venus on 28 March, Uranus is 14 arcminutes above it relative to the UK's horizon. Venus will be at mag. –3.8 on this date, while Uranus is mag. +5.9.

NEPTUNE

Not visible this month.

YOUR BONUS CONTENT Planetary observing forms

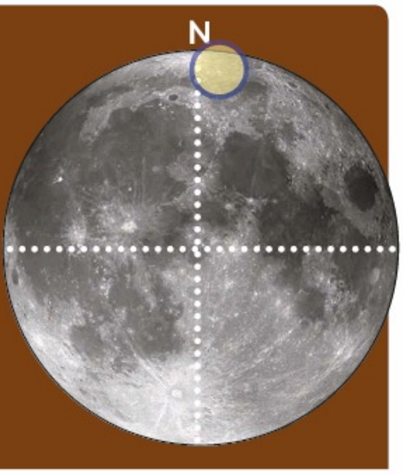


Libration reveals more of the crater complex close to the northern limb of the Moon

MOON**WATCH**

BARROW

TYPE: Crater
DIAMETER: 93km
LONGITUDE/LATITUDE: 7.6° east, 71.3° north
AGE: Between 3.85-3.92 billion years
BEST TIME TO SEE: 6 days after new Moon (24 March) or 5 days after full Moon (8 March)
MINIMUM EQUIPMENT: 50mm refractor



> **“Northwest of Barrow sits Goldschmidt, with Anaxagoras to the west”**

Crater Barrow lies close to the northern pole of the Moon. From Earth the consequence of this is the 93km-diameter crater appears extremely foreshortened as an ellipse and its appearance changes over time thanks to lunar libration. This is the term used to describe the fact that we don’t get to see exactly the same face of the Moon at all times. Variations in the Moon’s speed around its orbit combined with a 5° inclination of its orbit in relation to that of Earth, make it appear as if the Moon rocks and rolls on its axes. When libration tilts the northern limb of the Moon toward Earth, Barrow appears less foreshortened than when the limb is tilted away from Earth.

Foreshortened craters are harder to navigate than their more face-on counterparts because their ellipses have a tendency to merge into one muddled area. Barrow is surrounded by a number of craters that do a fairly good job of disguising it. When the phase allows, the easiest starting point is the dark, lava-filled crater Plato. With a diameter of 101km, Plato stands out clearly from the bright surrounding highlands. Move north from Plato across an area of highland material and you’ll end up in Mare Frigoris, the Sea of Cold. This is a highly elongated lunar sea, measuring 1,800km in length but just 200km in width.

On the northern shore of Mare Frigoris lies the small, well defined crater Timaeus, which at 33km is dwarfed by the massive walled plane of W Bond to the northeast. Barrow lies north and east of 160km W Bond, and is notable because of sharply defined 28km Barrow A interrupting its southwest rim. To the northwest of Barrow sits 121km Goldschmidt, with the prominent 51km ray-crater Anaxagoras immediately to the west. Ejecta rays from Anaxagoras can be seen to tiger-stripe the floor of Barrow when the Sun is high in Barrow’s sky.

Barrow’s rim is highest in the northwest where it connects with Goldschmidt and overall is very tortured, having been heavily eroded over time. The eastern portion of the rim has a break in it, which helps to form an interesting effect when the morning terminator is close by. At lunar co-longitude 2.5° the Sun isn’t high enough to illuminate Barrow’s floor, but can shine through the break in the rim. This creates a shaft of light that passes across the floor and is known as the Barrow Ray. When the ray is visible, a similar phenomenon can be seen in 54km Scoresby M to the north and in 56km Challis further north still. Libration has to be favourable to spot the Challis ray.

The Barrow ray should be visible around 17:00 UT on 24 March. The Sun will be up at this time but the effect should still be visible through a telescope. If you’re attempting to image the Barrow Ray, a mono high-frame-rate camera fitted with an infrared pass filter will give you the best contrast by darkening the blue daylight sky.

PETE LAWRENCE X 3

COMETS AND **ASTEROIDS**

18 Melpomene passes a host of galaxies as it follows a path across the Bowl of Virgo

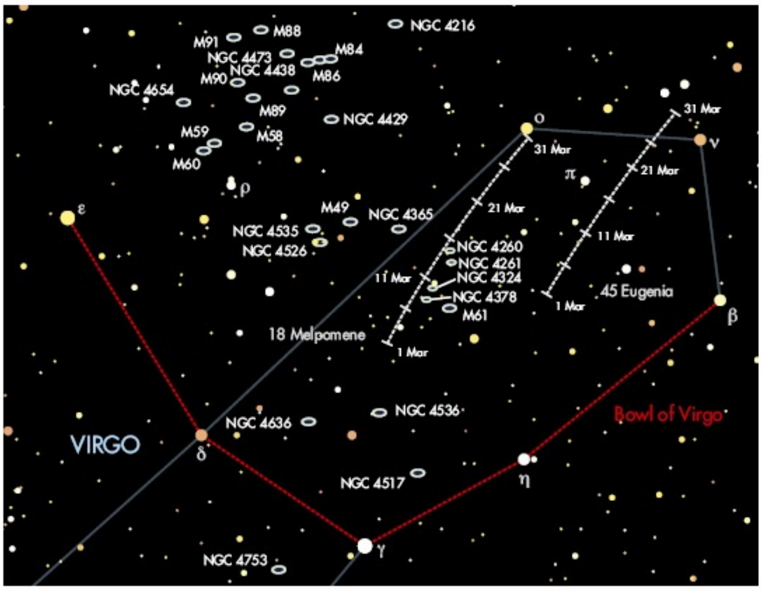
Minor planet 18 Melpomene reaches opposition on 21 March in the constellation of Virgo. This is a large, main-belt asteroid measuring 170x155x129km. Its orbit brings it as close as 268.5 million km (1.8 AU) to the Sun at perihelion and out as far as 418.4 million km (2.8 AU) at aphelion. It takes 1,270.6 days (3.5 years) to complete one orbit.

Melpomene is an S-type, silicaceous asteroid with a stony composition. It is relatively bright, varying between mag. +7.5 and +12.0. The 2018 opposition isn't particularly favourable in this respect, Melpomene reaching a maximum magnitude of +10.2. At the start of March, it'll appear at mag. +10.5, slowly brightening to mag. +10.2 by the 18th. It remains at this brightness through to the 24th, dimming back to mag. +10.4 by 31 March.

Melpomene's path takes it across a section of the Bowl of Virgo, a region rich in galaxies and there's an opportunity to watch it slowly track past some of these objects throughout the month. On the nights of 6/7 and 7/8 March, Melpomene appears close to NGC 4378 a mag. +11.7 spiral galaxy located 1° northeast of mag. +10.1 M61.

On the night of 9/10 March, Melpomene passes 20 arcminutes northeast of the mag. +11.6 lenticular galaxy NGC 4324. On 13/14 March the minor planet passes mag. +10.4 elliptical galaxy NGC 4261 and +11.8 barred-spiral NGC 4260. Melpomene passes less than 10 arcminutes northeast of NGC 4260 on the night of 14/15 March. Then on the night of 30/31 March, Melpomene completes its crossing of the Bowl of Virgo and sits 12 arcminutes south of the mag. +4.1 star Omicron (ο) Virginis.

Melpomene was found by the English astronomer John Russell Hind on 24 June 1852 and, following the occultation of a star on 11 December 1978 was believed to have its own moon. Later observations by the Hubble Space Telescope revealed the asteroid's elongated shape but no presence of a moon.



▲ 18 Melpomene seems to slowly track out of the Bowl of Virgo in March

STAR OF **THE MONTH**

Learn more about Regulus, Leo's brightest star

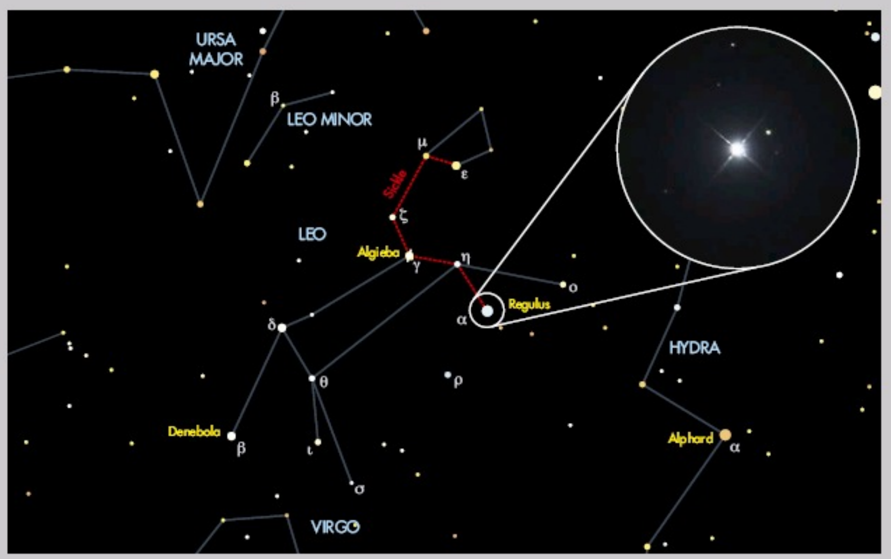
Regulus (Alpha (α) Leonis) is one of the principal stars of the spring sky. It's easy to spot at the base of the asterism known as the Sickle, a pattern representing the head of Leo. If you need further affirmation, follow the lines of both sides of the Plough's blade down and away from Polaris. With a bit of artistic license, they converge at Regulus.

Regulus is 79 lightyears from the Sun and appears to us at mag. +1.4, located 0.5° from the ecliptic. This location means that Solar System objects appear to interact with it and, as is the case currently, the Moon can occult Regulus. Planetary conjunctions with Regulus aren't uncommon but planetary occultations are rare. The next will occur on 1 October 2044, when Venus passes in front of the star.

Regulus is a multiple star system. An obvious mag. +8.2 companion sits 177 arcseconds away in a northwest direction (position angle 307°). This orange companion, Regulus B, is a double with a separation of 2.5 arcseconds between it and mag. +13.5 Regulus C. The B-C pair's orbital period is an estimated 600 years. This pales into insignificance compared to the 125,000 years it takes B-C to orbit the main Regulus A star.

Spectroscopic analysis of Regulus A reveals that it too is a double. Its so-far-unseen companion is believed to be a white dwarf star, orbiting Regulus A once every 40.11 days at a distance of just 52 million kilometres.

Another interesting characteristic of Regulus is its fast rotation rate of 317km/s. At this speed, Regulus will be flattened into an oblate spheroid, approximately one-third wider at the equator than its polar diameter. Its equatorial diameter is estimated to be 4.3 times that of the Sun.



▲ A close look at Regulus reveals a companion, which itself is a double star

STEPHEN TONKIN'S
BINOCULAR **TOUR**

Start this month's tour with a historical eye test and finish it by practising your averted gaze

☑ Tick the box when you've seen each one

1 MIZAR AND ALCOR

10x50 Before the invention of eye charts, stars were used to test visual acuity. When you could no longer see that the mag. +2.2 Mizar (Zeta (ζ) Ursae Majoris) and its mag. +4.0 companion, Alcor (80 Ursae Majoris), were separate stars, you needed spectacles. They are easy to split in binoculars, which also reveal a mag. +7.6 companion that lies 6 arcminutes south of Alcor and 8 arcminutes east of Mizar. Extend this line from Mizar through the fainter companion for 2.5° and you come to a reddish star, mag. +4.6 83 Ursae Majoris. ☐ **SEEN IT**

2 OΣΣ123

10x50 Our next stop is the double star, OΣΣ123, at the end of a 4° long chain of stars that extends west from Thuban (Alpha (α) Draconis). At mags. +6.6 and +7.0, the components are of a similar brightness that, combined with a separation of 69 arcseconds, makes them easy to split with hand-held binoculars. The 'OΣΣ' designates Otto Wilhelm von Struve's catalogue of double stars. ☐ **SEEN IT**

3 PHERKAD AND PHERKAD MINOR

10x50 Pherkad (Gamma (γ) Ursae Minoris) is one of the 'Guardians of the Pole' (the other is Kochab). It shines at mag. +3.0 and is the southernmost star of the 'bowl' of Ursa Minor's Little Dipper asterism. The mag. +5.02 pale orange Pherkad Minor (Gamma-1 (γ1) Ursae Minoris) is easy to spot, 17 arcminutes to the west. The stars are not a true binary, they're not even gravitationally bound to each other: Pherkad is 487 lightyears away while Pherkad Minor is 398 lightyears away, and they're moving in different directions. ☐ **SEEN IT**

4 POLARIS ASTERISM

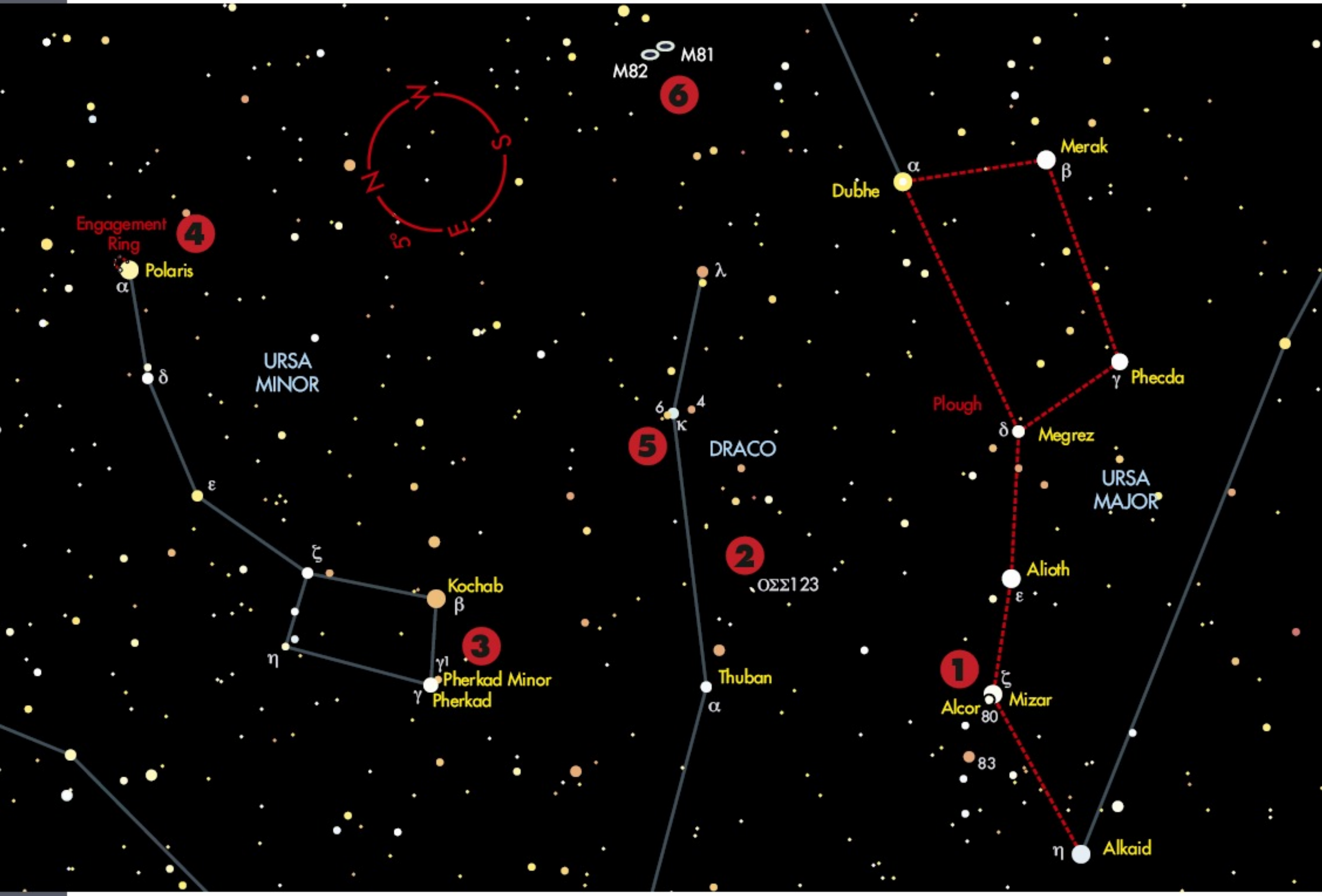
10x50 Many astronomers see Polaris (Alpha (α) Ursae Minoris) merely as a convenient marker for the North Celestial Pole (NCP), oblivious to the asterism of which it is part. 10x50 binoculars reveal that the mag. +2.0 Polaris blazes in a ring of mostly 8th and 9th magnitude stars, nearly a degree wide. One of the stars in the circlet is slightly displaced from Polaris, which bisects the line joining it and the NCP, enabling this more precise determination of its location. ☐ **SEEN IT**

5 KAPPA DRACONIS ASSOCIATION

10x50 Kappa (κ) Draconis is a hot (14,000K) B-type star that's 540 times more luminous than the Sun. To the north is a pair of orange K-type stars, the brighter of which is the mag. +4.9 6 Draconis, which is only about 300 times as luminous as the Sun. To the south is a star with a similar luminosity, the long-period pulsating variable (mag. +4.9 to +5.0) 4 Draconis. This is a cool M-type star whose surface temperature is a 'mere' 3,940K. ☐ **SEEN IT**

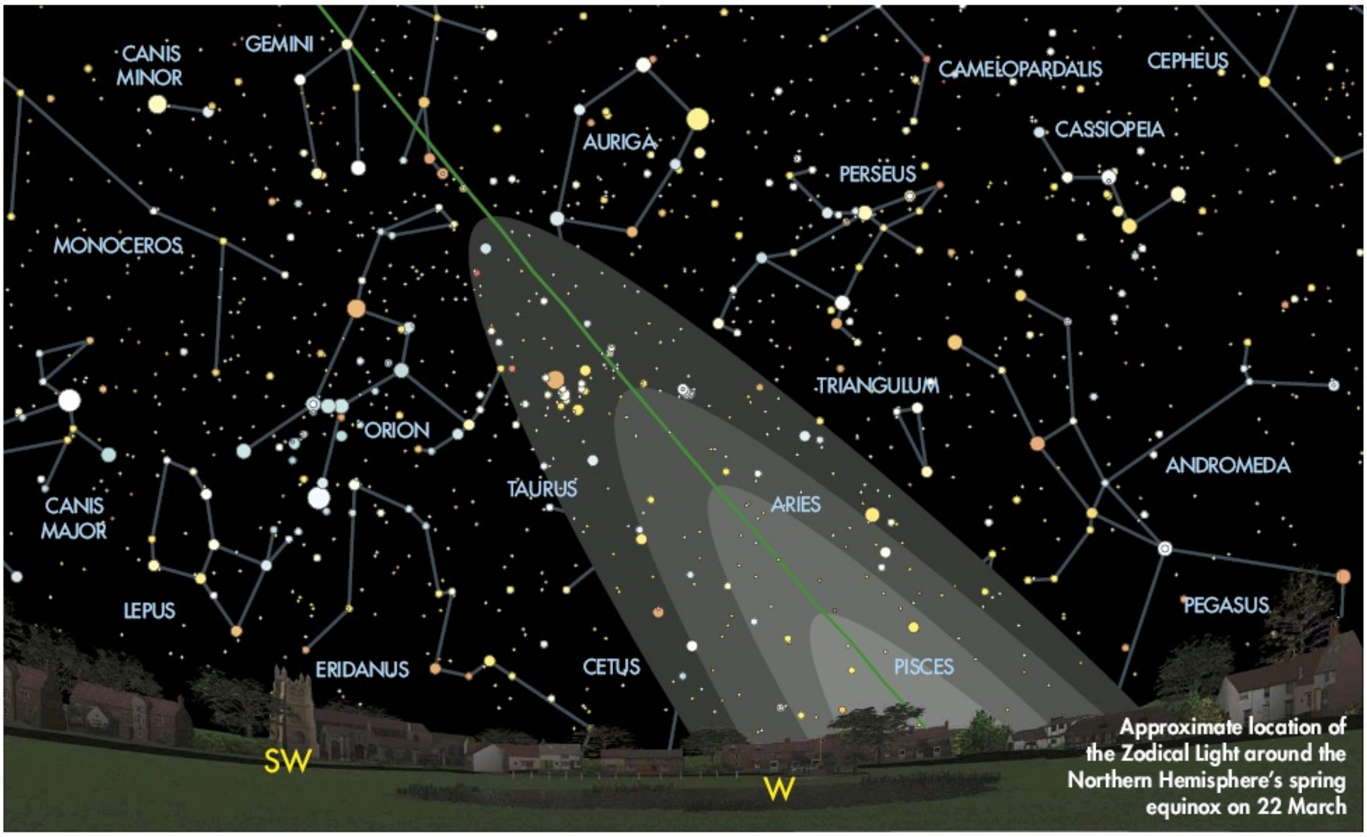
6 M81/82 GALAXY PAIR

15x70 In the north polar region of the sky you can find the galaxy pair M81 (Bode's Nebula) and M82 (The Cigar Galaxy). Take a line from Phecda (Gamma (γ) Ursae Majoris) through Dubhe (Alpha (α) Ursae Majoris) and extend it the same distance to the northwest. The galaxies should be at the end of this line; M81 is the brighter of the pair. The two galaxies are a useful target upon which to practise averted vision: as you direct your gaze at one, the other appears more clearly. ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

Look closely and the subtle shape of the Zodiacal Light may reveal itself this month



Approximate location of the Zodical Light around the Northern Hemisphere's spring equinox on 22 March

The Solar System is a dusty place. The majority of what's known as interplanetary dust is thought to have originated from Jupiter-family comets. These are short-period comets with orbits influenced by Jupiter's gravity. They typically have periods less than 20 years. The cometary dust is small with typical particle sizes in the range 10-300 microns. Over time, collisions further reduce particle size. Below 10 microns, dust is removed from the inner Solar System by radiation pressure but is continually replenished by around 400 Jupiter-family comets.

Sunlight interacting with the dust particles creates the Zodiacal Light phenomenon and this month's challenge is to to see and photograph it. Before you do, however, it's important to understand that the Zodiacal Light is extremely subtle and easily lost in even low-level light pollution. A good, dark sky is essential, as is perseverance.

As its name suggests, the phenomenon is connected with the Zodiac, the circle of constellations through which the Sun appears to travel during the year. In reality, it's the movement of the Earth along its own orbit that makes the Sun appear to move. The apparent path of the Sun defines the great circle known as the ecliptic.

Interplanetary dust occupies a lenticular-shaped volume centred on the Sun with most of the material concentrated along the ecliptic plane. Consequently the dust is best seen along the ecliptic and this gives us some clues as to the best times of the year to try and see it.

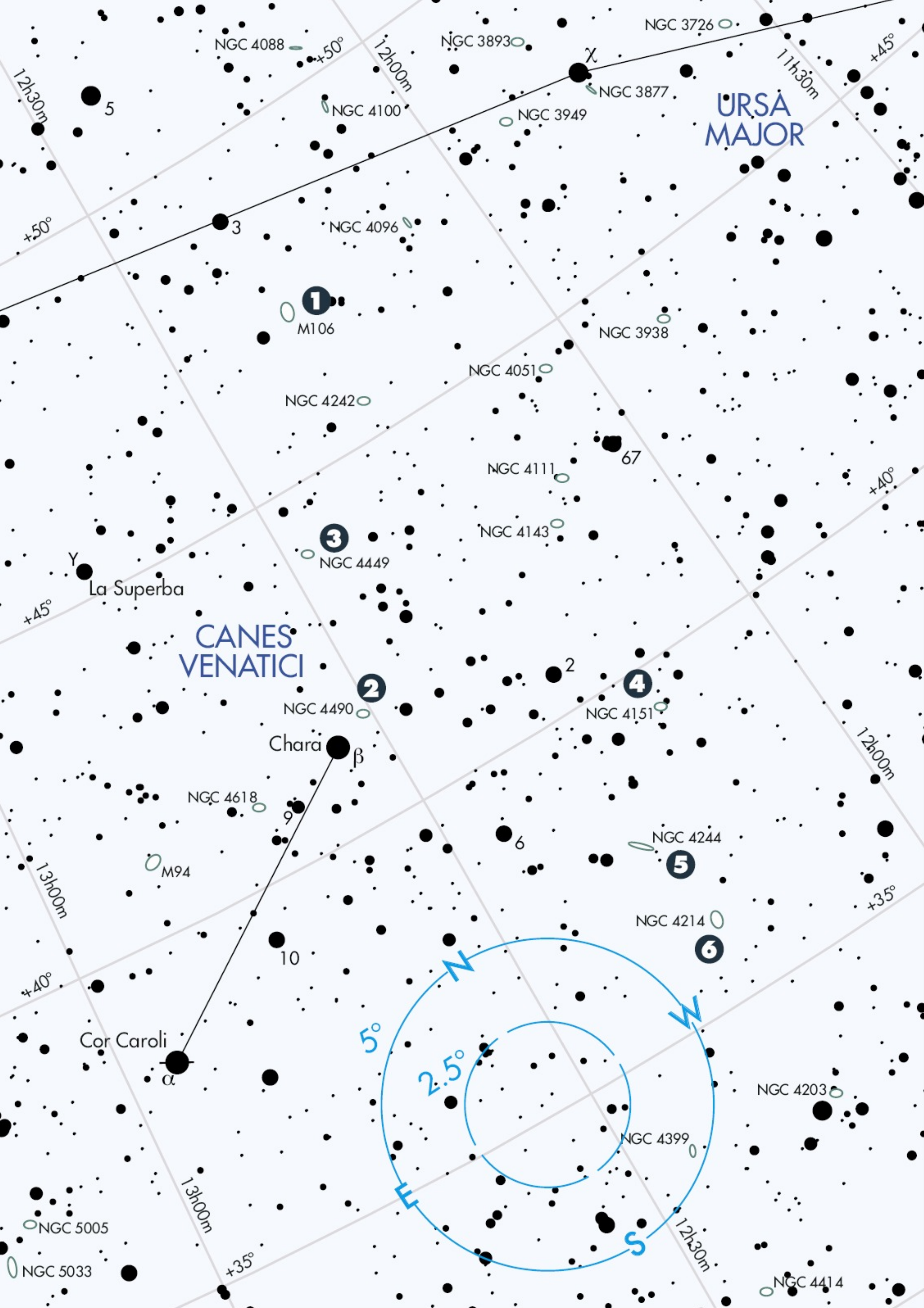
Certain months present better opportunities for mid-northern latitudes. Around the Northern Hemisphere's spring equinox for example, the Zodiacal Light is optimally tilted to the western horizon after sunset. This is because the ecliptic creates a steep angle with the western sunset horizon at this time of year. Around the Northern Hemisphere's autumn equinox, the same is true of the pre-sunrise ecliptic relative to the eastern horizon.

▲ This shot of the autumn Zodiacal Light taken in Selsey, West Sussex, on 11 October 2008 shows just how subtle the phenomenon is

When visible, the Zodiacal Light presents itself with a distinctive conical shape. The cone's vertical axis runs along the ecliptic and the edges of the cone bulge outward. The best time to try and see the Zodiacal Light is during the 90-minute window that starts 90 minutes after the Sun sets.

If you fail to see it visually, a wide-angle camera pointed in the directions mentioned above at the correct times may fare better. The camera should be set to produce a relatively deep but non-overexposed sky. A time-lapse sequence may also help because it can be played back to show whether the characteristic Zodiacal Light shape was really there. Do let us know if you manage to see or photograph it by posting your pictures on www.facebook.com/skyatnightmagazine or @skyatnightmag.

PETE LAWRENCE X 3


NGC 3726
NGC 4088
+50°
12h00m
NGC 3893
χ
+45°
11h30m
12h30m
5
NGC 3877
NGC 4100
NGC 3949
URSA
MAJOR
+50°
3
NGC 4096
1
M106
NGC 3938
NGC 4051
NGC 4242
67
NGC 4111
+40°
3
NGC 4143
NGC 4449
Y
La Superba
+45°
CANES
VENATICI
2
2
4
NGC 4490
NGC 4151
Chara
β
12h00m
NGC 4618
9
6
NGC 4244
M94
5
13h00m
+35°
NGC 4214
6
10
N
+40°
W
5°
Cor Caroli
2.5°
α
NGC 4203
NGC 4399
E
13h00m
S
12h30m
NGC 5005
+35°
NGC 5033
NGC 4414

DEEP-SKY TOUR

Stare into the Eye of Sauron as you travel around this month's skies

☑ Tick the box when you've seen each one

1 M106

Messier 106 is an intermediate spiral galaxy, a type that shows structure between that exhibited by barred and unbarred spirals. It has a bright active core that also classifies it as a Type 2 Seyfert galaxy. M106 has an apparent magnitude of +9.1 making it a good target for smaller instruments. It lies 6.5° northwest of Chara (Beta (β) Canum Venaticorum). The bright core stands out well for most apertures and appears mottled in a 150mm instrument. Using a large telescope you'll be able to see M106's inner core with its stellar nucleus, surrounded by two wide regions representing the galaxy's arms. ☐ **SEEN IT**

2 NGC 4490

Our next object is NGC 4490, another example of a barred-spiral galaxy. It's located in Canes Venatici and found by extending the line from Cor Caroli (Alpha (α) Canum Venaticorum) through Chara (Beta (β) Canum Venaticorum) by 1/10th. Here you should see mag. +9.8, NGC 4490 and its interacting partner galaxy, mag. +12.0 NGC 4485, 3.5 arcminutes away. Through a 150mm telescope they have the appearance of a small diffuse patch next to a larger diffuse patch. Their apparent size grows through larger instruments with a 250mm scope showing them touching. NGC 4485 appears circular while NGC 4490 has an elongated appearance with more structure. A number of brighter knots can be seen, especially close to the region where both galaxies appear to touch. ☐ **SEEN IT**

3 NGC 4449

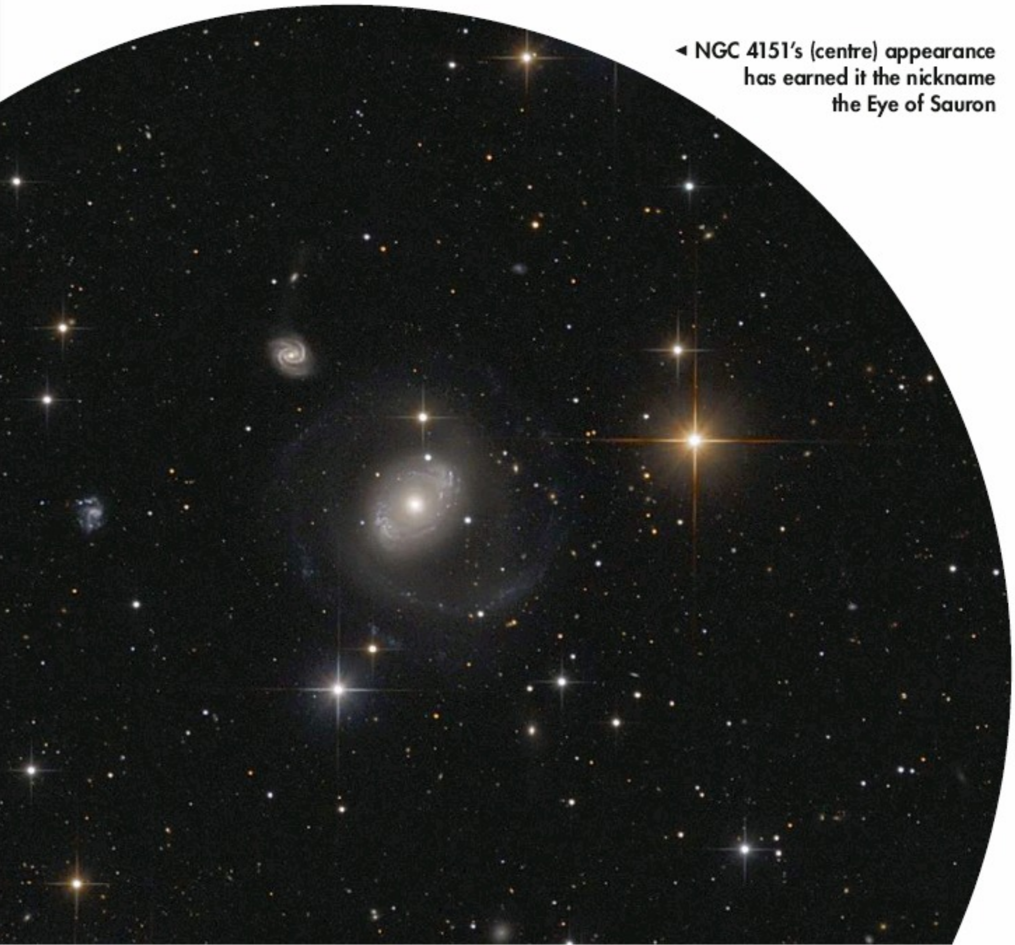
Heading 2.5° north from NGC 4490 brings you to the bright, irregular galaxy NGC 4449. This is a member of the Canes Venatici I group of galaxies, located 12 million lightyears away and a relatively close neighbour of the Local Group of Galaxies of which the Milky Way is a member. Parallels have been made between NGC 4449 and the Milky Way's own satellite galaxy, the Large Magellanic Cloud (LMC). A 150mm telescope shows this mag. +9.4 galaxy easily, but larger instruments are required to pull out detail such as its northeast-southwest elongation and non-uniform brightness. Brighter patches may also be seen near the core. A 300mm telescope brings the hint of a curving arm arching in a northwest direction from the main body of the galaxy. ☐ **SEEN IT**

4 NGC 4151

NGC 4151, 'The Eye of Sauron', is an intermediate spiral Seyfert galaxy, characterised by a highly luminous, active nucleus. The driving power behind this bright nucleus is thought to be a supermassive black hole or perhaps a pair of black holes, although there is still uncertainty about the latter. It lies approximately 5.5° southwest of NGC 4449 – roughly the same apparent distance between Chara and Cor Caroli. Smaller apertures show this mag. +10.4 galaxy as a star-like dot surrounded by a faint glow. Larger instruments will show the central core offset northeast of the glow's centre. The Eye of Sauron nickname refers to its appearance in images taken through the Hubble Space Telescope. ☐ **SEEN IT**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.



◂ NGC 4151's (centre) appearance has earned it the nickname the Eye of Sauron

5 NGC 4244

NGC 4244 sits 2.5° southeast of NGC 4151 and 2° southwest of mag. +5.0, 6 Canum Venaticorum. It's a mag. +10 edge-on spiral galaxy with the appearance of a thin 'needle' of light against the background sky. A 150mm telescope shows this incredibly thin needle well. It appears 10x1 arcminutes with a delicate inner core, slightly brighter than the main 'needle'. Increasing aperture serves to further emphasise the sharpness of the needle. A 300mm telescope expands the apparent size to 15x1.5 arcminutes. Non-uniformity also begins to appear, dividing its length into sections. The overriding impression from looking at NGC 4244 throught the eyepiece is how sharp both ends of its elongated shape actually appear. ☐ **SEEN IT**

6 NGC 4214

Our final target is the irregular galaxy NGC 4214. Locate it by extending a line from Chara through 6 Canum Venuaticorum for 1.2x that distance again. This is a relatively bright mag. +9.7 galaxy that presents a circular glow approximately 1.5 arcminutes across through a 150mm instrument. As NGC 4449 was compared with the LMC, so NGC 4214 is often compared to the Small Magellanic Cloud, albeit as a larger and brighter version. The galaxy contains several huge HII regions at its centre where star formation is occurring. A 250mm scope shows the galaxy to have irregular shape with a small, diffuse but bright spot at its centre. A 300mm scope shows the central region to be broad and elongated. ☐ **SEEN IT**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: MARKUS BLAUENSTEINER/CCDGUIDE.COM

ASTROPHOTOGRAPHY

Twilight photography

RECOMMENDED EQUIPMENT

Digital camera, tripod.

▲ Incorporating the brightness of twilight and the darkness needed to catch planets can be tricky

ALL PICTURES: PETE LAWRENCE

There are some great opportunities to catch Mercury, Venus and the Moon in evening twilight this month. With the Northern Hemipshere's spring equinox occurring on 20 March, this is a great time of year to view evening planets and the earlier phases of the Moon, in the west after sunset. This is because the ecliptic plane is starting to make a steep angle with the western horizon at sunset. As the planets and the Moon tend to remain close to the projection of this plane across the sky, a great circle known as the ecliptic, they tend to remain higher in the western sky after sunset than at other times of the year.

Mercury and Venus appear to dance with one another throughout the month, joined by a thin crescent Moon on 18 March. Dazzling though these objects can seem – especially Venus – they can be tricky to photograph well due to the background twilight sky.

By its very nature, an evening twilight sky is unevenly illuminated, brightening towards the region where the Sun has recently set. Variations in the quality of the atmosphere as well as cloud cover mean that settings used for one twilight shoot won't necessarily be appropriate for another. An incorrectly set camera may overexpose the background sky causing you to lose the Moon or planets. Underexposure will create a scene that looks too dark and moody.

Then there's the question of image scale. Use too wide a lens and bright planets that look so stunning to the naked eye will appear as tiny, hard-to-see dots against a bright sky. Use too high an image scale and the context becomes lost because it'll be difficult to frame objects with the horizon. For evening twilight photography, it's possible to wait for your targets to lose altitude as they approach setting. But wait too long and the thicker layer of atmosphere their light has to pass through will cause them to appear overly dim, removing the effect that inspired you to photograph them in the first place.

KEY TECHNIQUE

USE THE REVIEW SCREEN

Morning and evening twilight are beautiful periods that pose interesting challenges for astrophotography. Ever-changing light levels and background sky gradients mean that it's necessary to maintain a careful watch on your camera settings. Here, your camera's review screen is your greatest ally, allowing you to switch to manual settings and monitor each photo as it is taken. Careful adjustments can be made according to what the review screen shows, giving you opportunity to tweak things to achieve the perfect shot. But your camera can only go so far – the final composition is down to you.

As should now be becoming clear, there's a lot more to twilight photography than you might think. As well as the considerations previously mentioned, correct settings may not last long because as the Sun dips ever lower below the horizon, so the brightness of the sky continues to change.

The end of astronomical twilight occurs when the Sun reaches an altitude of 18° below the horizon and no longer affects sky brightness. Between astronomical twilight ending and starting again, the sky reaches a steady state of true darkness. The trouble is, by the time this condition has begun, the western planets will have set.

The brightness of the twilight sky often facilitates the use of basic automatic cameras, such as those built into smartphones. There is generally enough light present to allow such devices to both focus and determine settings. Often automatic settings aren't conducive to capturing planets or the Moon and here the use of a third party app that will give you more control is recommended. Using such an app, it should be possible to emulate the settings recommended in the step-by-step guide.

Also, in the step by step guide we show you how to approach twilight photography and give you some tips on how to capture this month's close conjunctions between Mercury, Venus and the Moon. Find out more about this conjunction on pages 52 and 56.

✉ Send your images to:
hotshots@skyatnightmagazine.com

STEP BY STEP

STEP 1

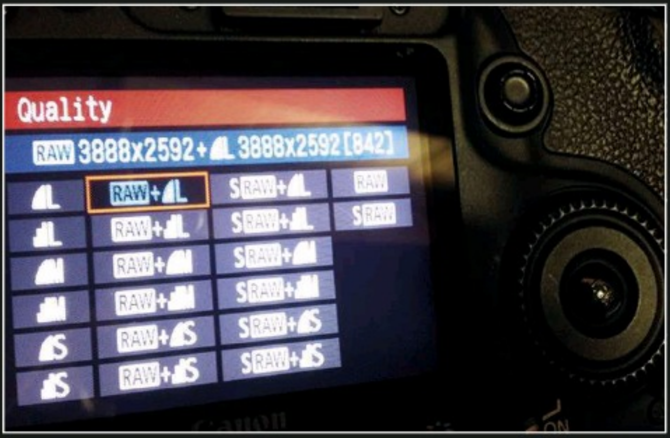
Focal length determines image scale. Too high a scale may give you a few bright dots against a featureless sky. Too low and your evening targets will be lost. For this month's targets, we'd suggest a frame at least 18° high. For a full-frame DSLR this means using a lens with around 70mm focal length or about 45mm for a non-full frame model.

STEP 2

A location with a flat horizon will give you a clear view of your targets but may end up looking a bit bland. Choose a location that gives you a relatively flat horizon but with some foreground interest too. Even wispy clouds can enhance twilight shots. Be careful not to overdo this, or you'll end up not being able to see what you came to photograph.

STEP 3

Mount your camera on a tripod, then frame and compose your scene. A landscape orientation with some horizon along the bottom of the shot gives your image some context. Make sure the horizon runs parallel to the bottom of the frame. Some cameras have level indicators built in so it's worth checking manuals to see whether yours has this facility.

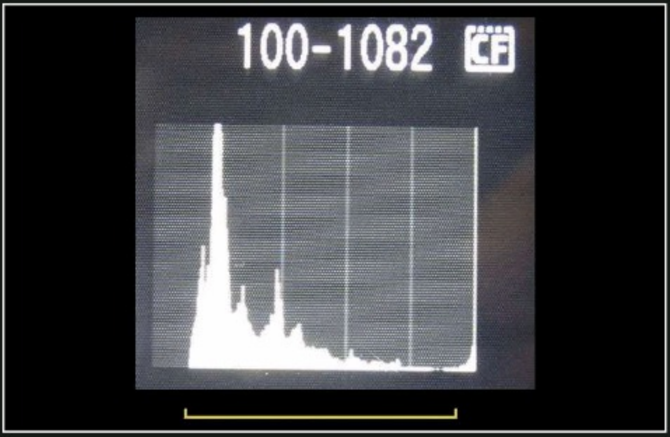


STEP 4

Initial settings depend on the scene brightness and your setup. Use a low ISO value if you can, about 100-800, as this will help keep unwanted noise down and result in a more tonally rich end result. Shooting in the RAW format offers more adjustment options post capture. If you're new to RAW, shooting in RAW + large JPG is recommended.

STEP 5

Set the lens to manual focus and focus on Venus. Select the lowest f-number then dial this back a stop or two. A fully open lens gives the best light gathering capability but could also introduce edge distortions. Set an exposure of one second and take a test shot. If the review image looks too bright, reduce the exposure; if it's too dark, increase it.



STEP 6

Avoid extending exposure beyond 500/focal length (FL) seconds. If you need to go longer, try raising the ISO. Check the review image's histogram. Ideally, the main part of the graph needs to sit between the two end points. Adjust your settings to achieve this but review and change them often to cope with the changing light levels at twilight!

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THE TRAVELLING NATURALIST

THE NORTHERN LIGHTS

With holiday companies releasing details of their latest aurora tours, now's the time to start thinking about booking your trip to see the Northern Lights. Remember one thing... never take your eyes off the skies, you never know when that spectacular display might appear.

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ABOUT THE WRITER
Govert Schilling is the author of *Ripples in Spacetime*, the story behind the detection of gravitational waves

TESS to impress

Scheduled to launch this month, TESS is the first of a new wave of exoplanet-hunting space telescopes that will scour the skies for new worlds, writes **Govert Schilling**

Columbus would've been envious. The famed explorer and navigator stumbled upon one 'New World' in the course of his lifetime. Over the next couple of years, astronomers expect to find a possible new world every hour. In the spring of 2020, the number of candidate exoplanets – planets orbiting stars other than our own Sun – may well be six times the current tally of confirmed ones, 3,584.

NASA's new exoplanet hunter TESS (Transiting Exoplanet Survey Satellite) is expected to be responsible for much of this increase. Perched on top of a SpaceX Falcon 9 launcher, the spacecraft is scheduled to be fired into orbit from Cape Canaveral on 20 March. "Until the late 2020s, no other mission than TESS will carry out these kinds of observations," says the TESS mission's principal investigator Dr George Ricker of the Massachusetts Institute of Technology (MIT).

TESS builds on the success of its predecessor, NASA's Kepler space telescope. During its four-year primary mission, Kepler studied some 150,000 faint, distant stars in the constellations of Cygnus and Lyra for signs of orbiting planets. But TESS will search the whole sky, focusing on a few hundred thousand stars brighter than mag. +12, most of which are much closer to the Sun than the stars in the Kepler catalogue. It may even find planets around some naked-eye stars. "This is a true discovery mission," says astrophysicist Professor Sara Seager, who is MIT's deputy science director for TESS. (See 'What I really want to know is…' on p106 for more from Sara Seager and her work on exoplanets.)

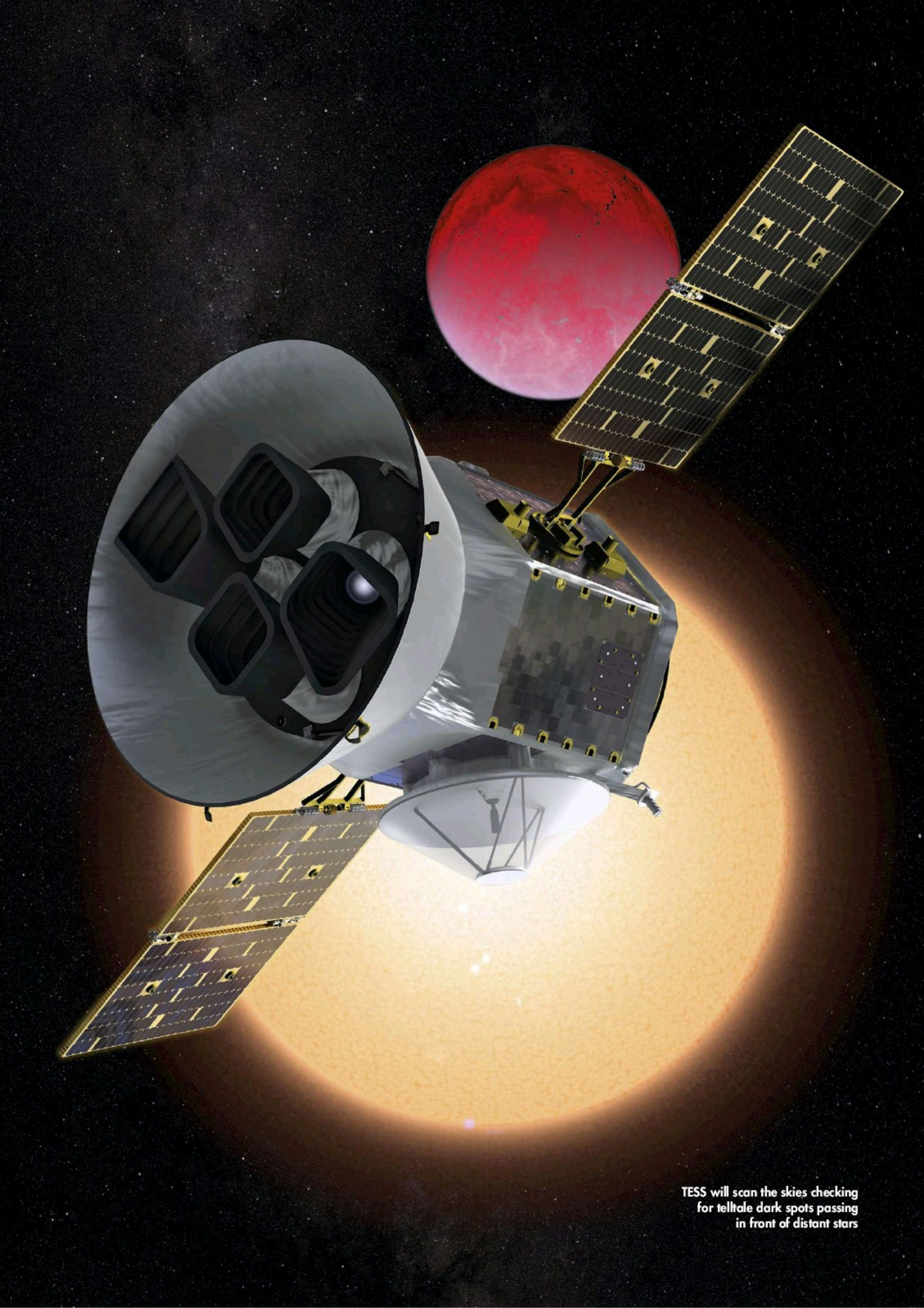
A dimming of the light

When an exoplanet's orbit is observed edge-on, it crosses the face of its parent star once per revolution. This transit results in a minute, temporary drop in the star's brightness. Since the size of a star is generally known, the change in its brightness, or 'transit depth', can be used to tell you the size of the exoplanet passing in front of it. Subsequent measurements of the star's 'wobble' – due to the gravitational tug of the exoplanet – can reveal the planet's mass. With these two properties, ▸

NASA'S GODDARD SPACE FLIGHT CENTER

YOUR BONUS CONTENT

Go to www.skyatnightmagazine.com/bonuscontent to download and watch our video interview with TESS principal investigator Dr George Ricker and find out more about this exciting mission.



TESS will scan the skies checking
for telltale dark spots passing
in front of distant stars

"TESS is expected to find some 20,000 exoplanet candidates in its first two years of operation"

▸ astronomers can extrapolate further characteristics, such as the exoplanet's density and makeup. Using the transit method, Kepler has found dozens of more or less Earth-like rocky planets, including a few orbiting in the habitable zone of their parent stars, where temperatures allow for the existence of liquid water and possibly life.

TESS is going to vastly improve on Kepler. Originally designed in 2006 at MIT with seed money from Google and the Kavli Foundation, it was first proposed to NASA in 2008. It was finally selected as part of the agency's Explorer programme in the spring of 2013, around the time Kepler's primary mission came to an end due to the failure of two of its reaction wheels, which are used to orientate the spacecraft. According to Seager, TESS is expected to find some 20,000 exoplanet candidates in its first two years of operation. "For at least a few dozen Earth-like worlds, both sizes and masses will be determined," she says.

Seeing the big picture

TESS is a relatively small spacecraft, outfitted with an array of four sensitive, wide-angle cameras. Each camera has a 16.8 megapixel detector and a huge field of view of 24x24°. Together, the cameras cover a large swathe of sky (a 'sector' in TESS parlance) that reaches from the ecliptic (the central plane of our Solar System) to one of the ecliptic poles (the two points on the sky perpendicular to the ecliptic).

The whole sky is divided into 26 of these sectors – 13 in the northern sky and 13 in the southern sky. Each sector will be monitored for about four weeks, with two-second exposures being taken every two minutes. In its first year of operation, TESS will focus on the northern sky; in its second year, the cameras will be aimed south.

NASA'S GODDARD SPACE FLIGHT CENTER X 3, ISTOCK X 3

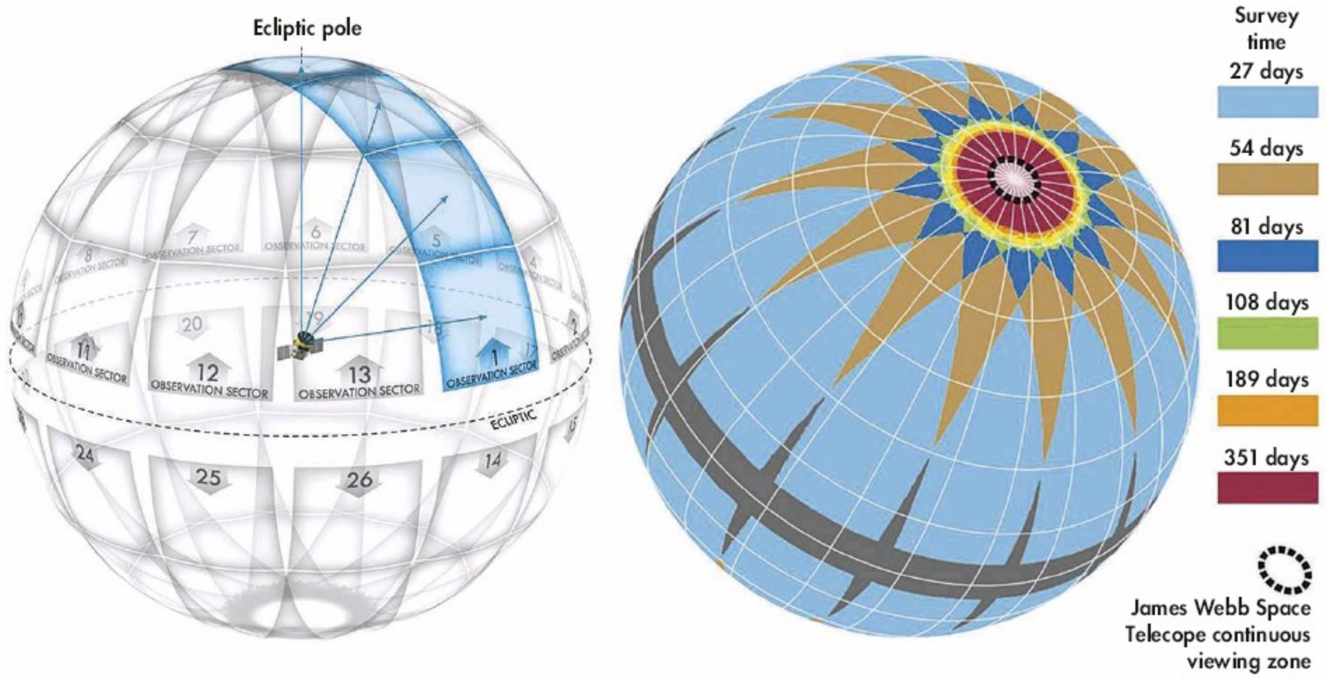
Is there anybody OUT THERE?

If life does exist on exoplanets, its fingerprints could be discovered in the light from distant stars

It's the million-dollar question that astronomers – and biologists – are trying to answer. We now know that planets are plentiful and that the simple carbon-bearing building blocks of life can be found all across interstellar space. But so far, Earth is the only planet known to harbour living organisms. And although many exoplanets orbit in the habitable zone of their parent stars, being habitable isn't quite the same as being inhabited.

During a transit, however, a tiny amount of starlight passes through the planet's atmosphere before reaching Earth. Atmospheric molecules leave telltale spectroscopic 'fingerprints' in the light of the parent star, mainly at infrared wavelengths. Future giant ground-based telescopes, as well as NASA's James Webb Space Telescope (JWST), due to launch in the spring of 2019, will be able to detect these so-called biomarkers – chemical compounds such as oxygen, ozone and methane – that are most likely to be produced by biological activity on the planet's surface.

"TESS will deliver the observational targets for JWST," says Dr Elisa Quintana of NASA's Goddard Space Flight Center. Whether the million-dollar question will be answered any time soon, however, is anybody's guess.

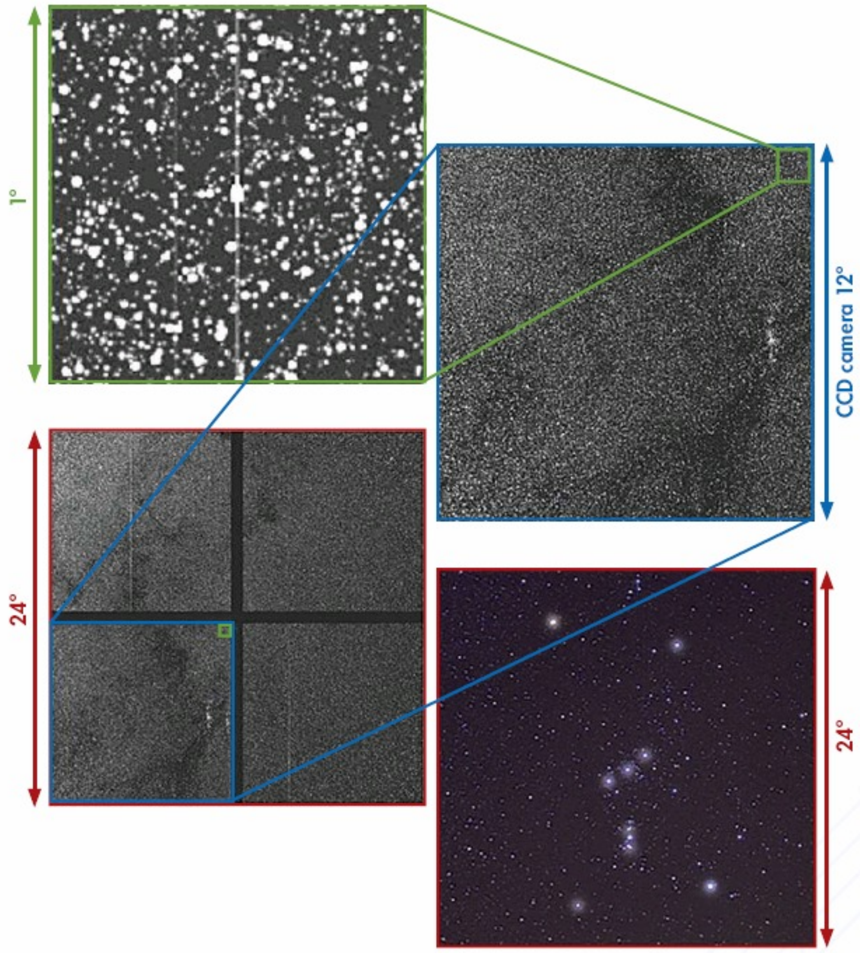


▲ TESS will spend 27 days surveying each of its 13 observing segments in both the northern and southern hemispheres. The overlap between sections towards the ecliptic poles means certain areas will be under almost-constant scrutiny.

Since each sector is observed for only four weeks and three transits are generally required to confirm the existence of an exoplanet, TESS will mainly discover short-period exoplanets that orbit close to their parent stars. From Kepler observations, we know that these are plentiful. Longer-period planets may be found closer to the north and south ecliptic poles, where sectors overlap.

To facilitate the observing strategy, TESS will be brought into a strongly tilted, highly elliptical and very stable high-Earth orbit, with its lowest point (perigee) at 108,000km and its highest point (apogee) at 373,000km, almost as far away from Earth as the Moon is. After launch, a lunar-gravity-assist flyby will help TESS slide into its final orbit, which will have a period of 13.7 days, half the orbital period of the Moon.

Once per orbit, around the point at which TESS reaches perigee, data from the preceding two weeks will be beamed to a ground station on Earth in a three-hour telecom session. The high-Earth orbit keeps TESS's sensitive detectors and electronics well outside the potentially damaging influence of Earth's Van Allen radiation belts.



▲ Each of the four cameras aboard TESS has an extremely wide 24x24° field of view. For a sense of scale, the constellation of Orion fits entirely within just one of these camera's fields of view

In closer detail

During the first few months of TESS's mission, European scientists will be preparing for the launch of CHEOPS (CHaracterising ExOPlanet Satellite), a smaller but more sensitive instrument that started out as a Swiss project but is now an official European Space Agency mission.

"CHEOPS is really a follow-up mission," explains principal investigator Professor Willy Benz of the University of Bern, Switzerland. "It won't make new discoveries, but it will study known transiting planets in much more detail, to derive very precise ▸

▸ radii." CHEOPS is a 30cm space telescope with a high-precision photometer that will study one star at a time during its 3.5-year mission.

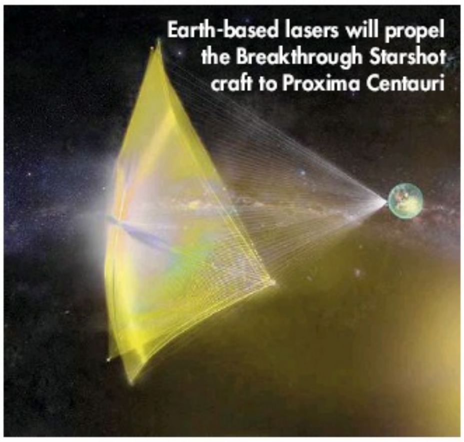
And, eight years from now, ESA plans to launch its versatile PLATO mission (PLAnetary Transits and Oscillations of stars), which could be described as TESS on steroids. Using no fewer than 26 small telescopes, PLATO will spend at least four, and possibly eight, years on a search for longer-period planets around up to a million stars. It will focus on Earth-like planets orbiting in the habitable zones of Sun-like stars and it may very well discover the first true Earth analogue, assuming that discovery hasn't already been made by TESS.

By then, NASA's James Webb Space Telescope (JWST), as well as sensitive instruments on extremely large ground-based telescopes, will regularly sniff out the atmospheric composition of transiting planets for traces of biomarkers such as oxygen, ozone and methane. Much of the work done by JWST will follow up on observations already carried out by TESS, as TESS searches the skies for potentially interesting targets. "TESS is a finder scope for James Webb," says Ricker. "It will tell us where we want to point the JWST to characterise Earth-like worlds." It seems the coming decades will usher in a new era in the search for exoplanets, and the launch of TESS is just the beginning of that exciting journey.

ISTOCK X 2, ESA/C. CARREAU, THALES ALENIA SPACE, NORTHRUP GRUMMAN, BREAKTHROUGH INITIATIVES

A long way FROM HOME

Planetary flybys have provided fascinating insights into the Solar System's members. Now we need to encounter the exoplanets



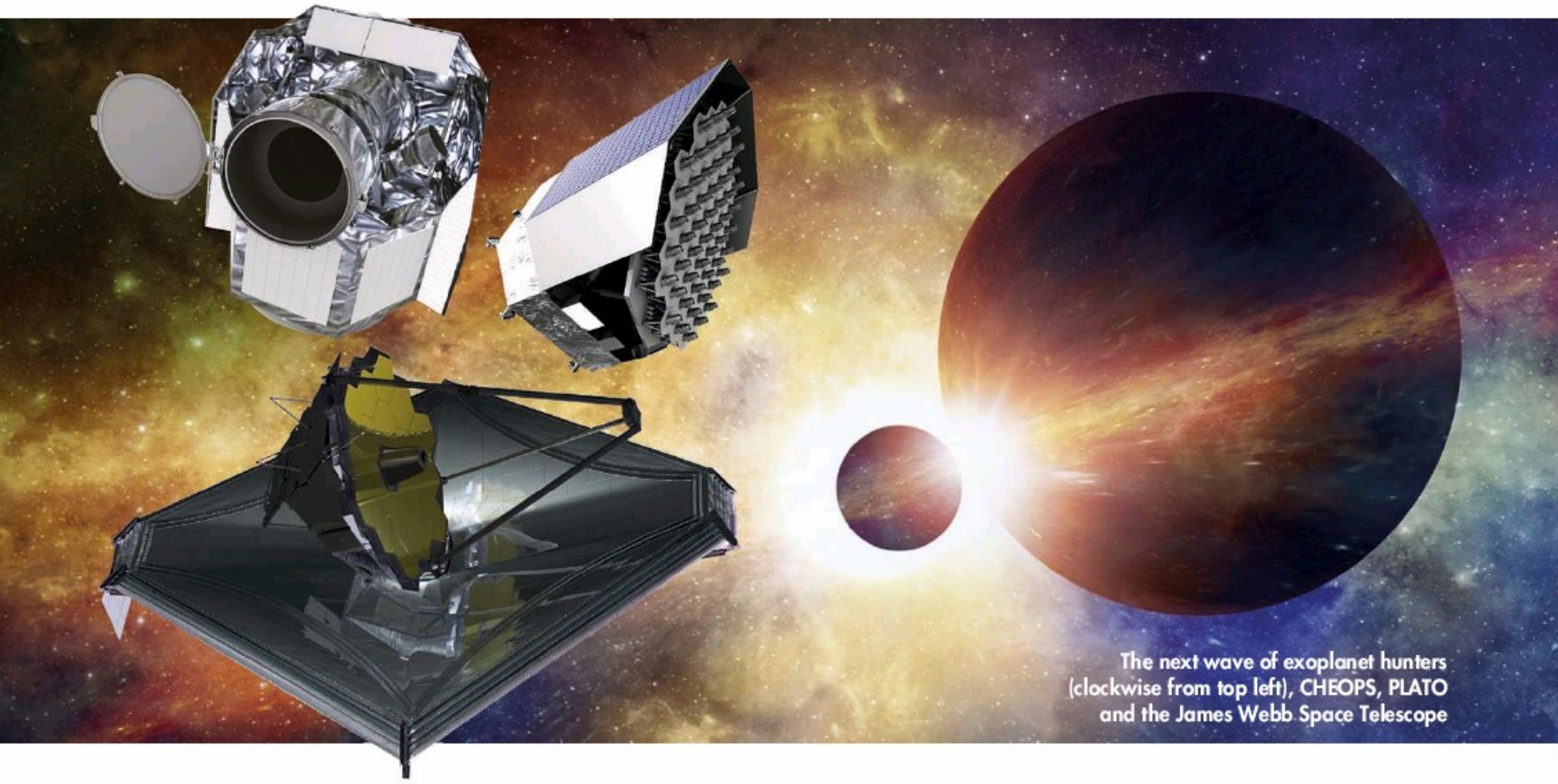
Earth-based lasers will propel the Breakthrough Starshot craft to Proxima Centauri

By far the best way to study an exoplanet would be to send a spacecraft to go and take a look at one. The Breakthrough Starshot project, funded by Russian billionaire Yuri Milner and supported by British cosmologist Stephen Hawking, is planning to do just that. But it's going to be tough (not to mention expensive) and it won't happen any time soon.

The nearest known exoplanet, Proxima Centauri b, is 4.2 lightyears away, some 40 billion kilometres. Even at 20 per cent of the speed of light (c), it will take over 20 years to get there. By comparison, Voyager 1, the fastest spacecraft humans have ever launched into space, only travels at 0.007 per cent of light speed.

Breakthrough Starshot's plan is to launch a swarm of tiny lightweight satellites into space. Each satellite will have ultra-thin light sails. A huge array of extremely powerful lasers on Earth will fire beams at the sails to accelerate the craft to 0.2c within minutes. The stamp-sized 'nano-craft' will carry cameras and spectrographs to collect data during the trip through the Proxima system.

Images and data would then take another 4.2 years to reach Earth. So if Breakthrough Starshot were to launch in 2030, which is extremely optimistic, our first exoplanet close-ups won't reach us until 2055 at the earliest. Until then, we'll have to make do with artistic impressions of any potential twins of our home planet.



The next wave of exoplanet hunters (clockwise from top left), CHEOPS, PLATO and the James Webb Space Telescope

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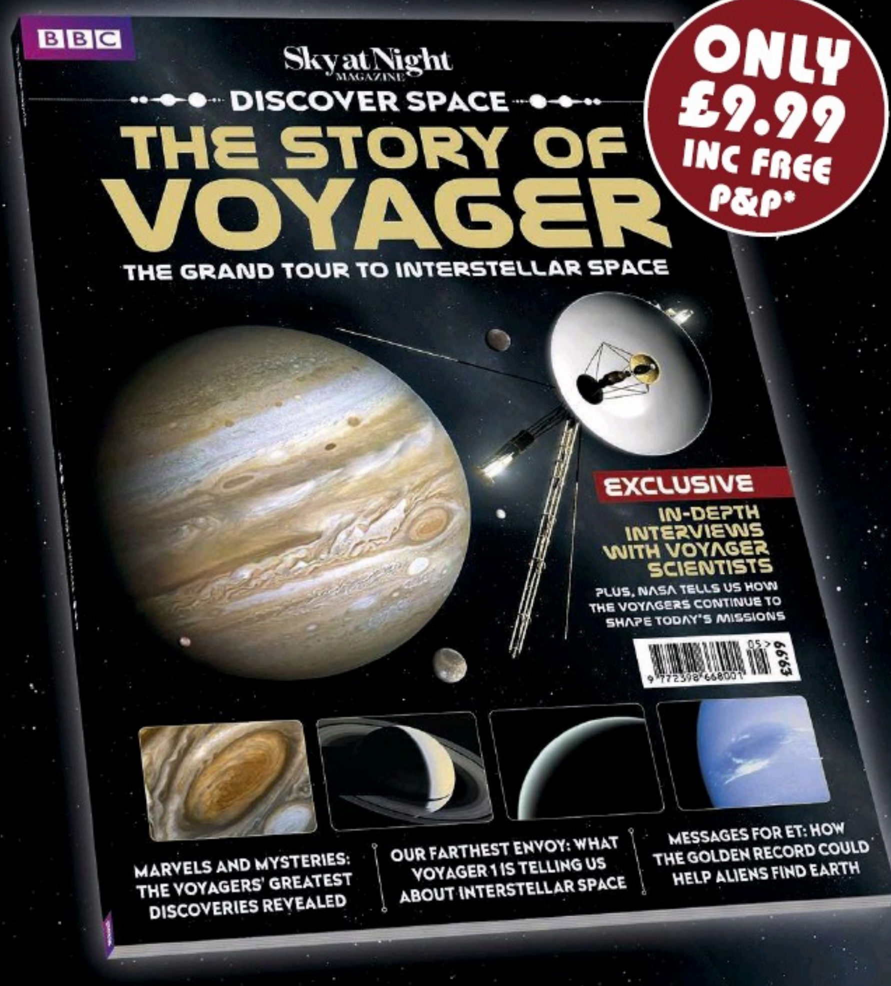
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Farewell to the flares

The 50 or so glinting Iridium satellites in low Earth orbit have garnered a cult following. Now it's time to bid them 'flarewell', writes **Jamie Carter**

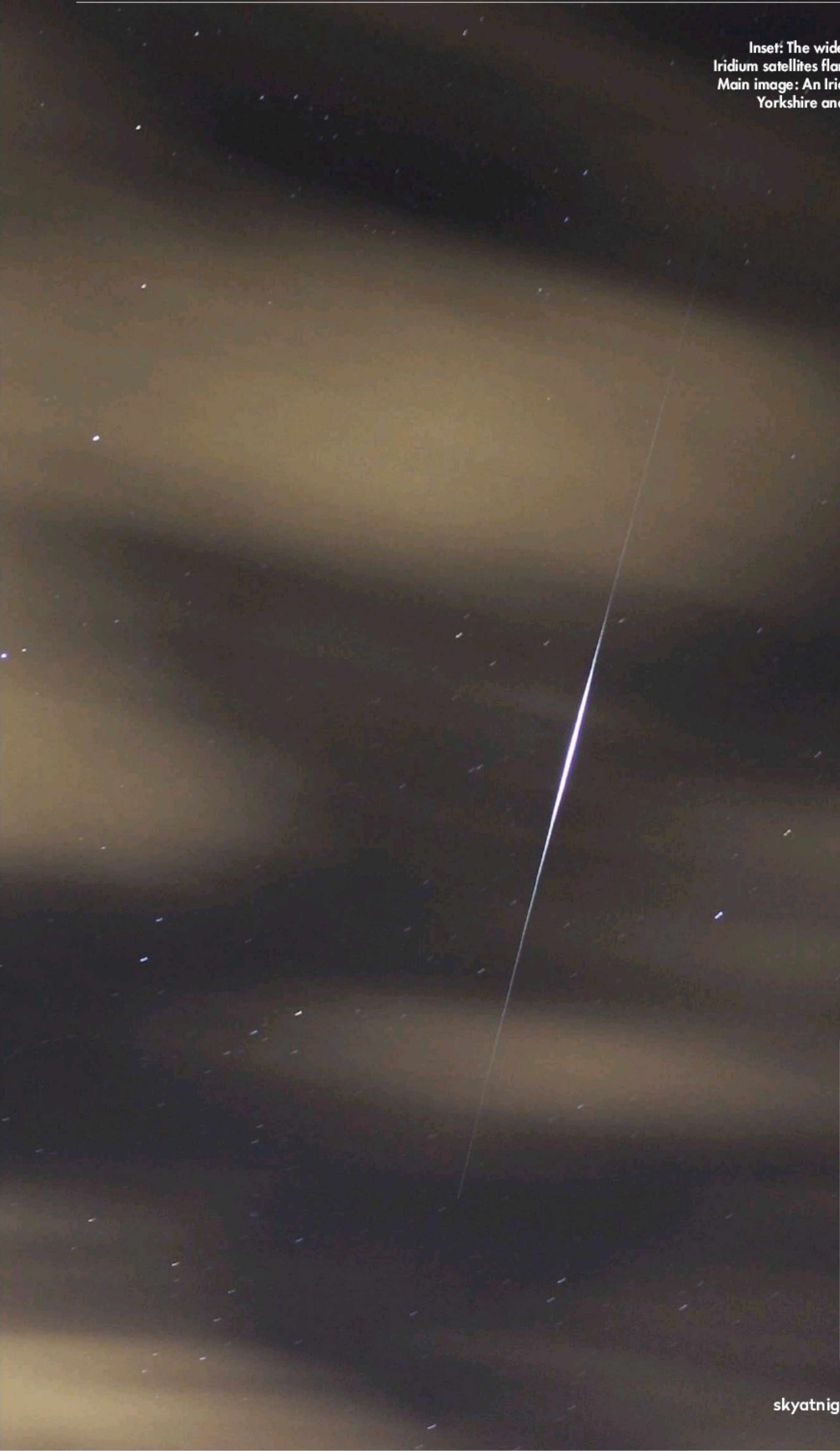
Have you ever seen an Iridium flare? When the Iridium fleet of 66 communications satellites was launched in the late 1990s, no one thought that the sunlight glinting off their panels would become a stargazing staple. Yet anyone regularly observing the night sky in the few hours after dusk and before dawn will probably have seen the unmistakable waxing and waning of an Iridium satellite's glint; they tend to last between five and 20 seconds and can reach mag. –8, brighter than Venus.

Iridium flares are caused by the satellites' three reflective panels catching sunlight, but the 50 or so that remain in orbit won't do so for much longer. Over the coming year, Iridium Communications – the company that owns the satellite network – is replacing it with a constellation of newer, smaller satellites. And to the dismay of the astronomers and astrophotographers who've grown used to spotting and photographing the Iridium satellites, these new ones don't flare.

Who cares? Iridium flare-hunters, that's who. For amateur astronomer Steve Brown, from Stokesley in North Yorkshire, Iridium satellites have become ▸

STEVE BROWN, IRIDIUM COMMUNICATIONS INC

Inset: The wide panels of first-generation Iridium satellites flare when sunlight hits them. Main image: An Iridium flare seen over North Yorkshire and captured by Steve Brown



ABOUT THE WRITER

Jamie Carter is the author of *A Stargazing Program for Beginners: A Pocket Field Guide* and edits WhenIsTheNextEclipse.com

A spectacular mag. –7.9 Iridum flare caught by Mary McIntyre on 4 August 2014

▸ part of his regular observing routine and he's been taking photos of them for the past three and a half years. "When I saw my first one I was amazed by the beauty of it – a star-like point of light moving against the dark sky that gradually brightened over a few seconds to become almost dazzling, before fading again," he says. Although Brown's neighbours are used to seeing him out with his camera, he frequently has to explain to them what he's taking a picture of. "For people who haven't heard of them before, the response is usually 'Iridium what?' But they're always amazed when I explain and then they see the flare."

What comes next

Although Iridium flares will soon be missing from the night sky, hobbyists such as Brown have been granted a long goodbye (or should that be flarewell?). Iridium Communications is now halfway through a launch programme with SpaceX to replace its entire fleet with new Iridium NEXT

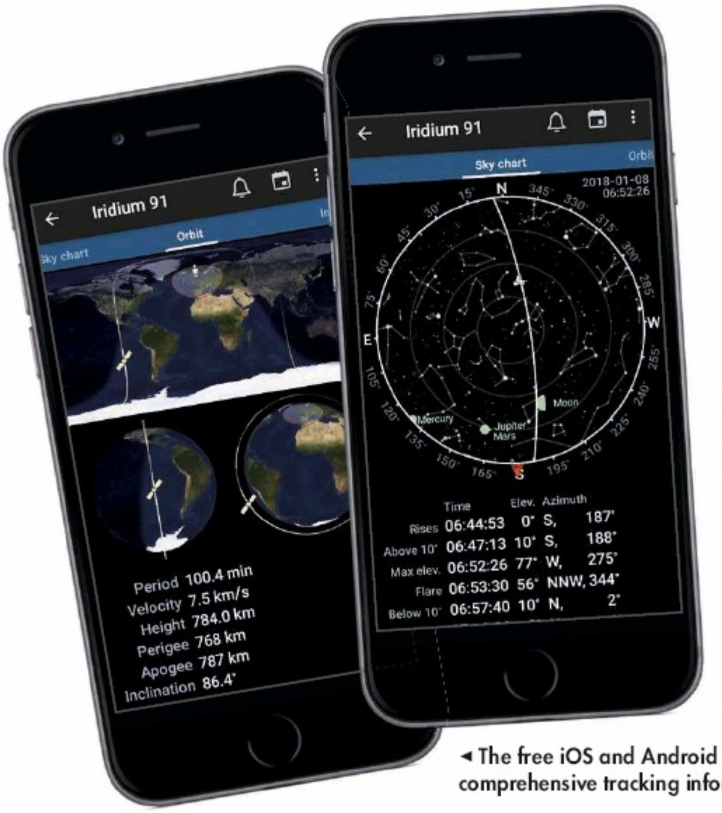
> "I so badly want to photograph the entire Iridium network, it's become quite an obsession"
> Mary McIntyre

How to... FIND A FLARE

Locating and imaging Iridium flares can be tricky but smartphones make the tasks a bit easier

Although they only last between five and 20 seconds, most Iridium flares are highly predictable. "When I'm outside on an unplanned observing session I use two apps, Heavens-Above and Stellarium, which give the orbital track and the exact flare point," says astrophotographer Nikki Young, 41, from Hampshire. "If I know that the skies will be clear enough, I like to pre-plan what I want to observe so I use a very useful website called CalSky (www.calsky.com) and write down all the information I need for the evening." CalSky also provides details of tumbling Iridiums, which are out of control, either defunct or soon to burn up.

As well as finding Iridium flares, a smartphone can also be used to image them. "Imaging with an iPhone was revolutionised by an app called NightCap Camera," says astrophotographer Andy Stones from North Lincolnshire, who has photographed the full Iridium satellite network using a smartphone. "Its Light Trails mode makes imaging satellite flares as successful as DSLR cameras."



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Period 100.4 min
Velocity 7.5 km/s
Height 784.0 km
Perigee 768 km
Apogee 787 km
Inclination 86.4°
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            Time     Elev. Azimuth
Rises       06:44:53  0° S,     187°
Above 10°   06:47:13 10° S,     188°
Max elev.   06:52:26 77° W,     275°
Flare       06:53:30 56° NNW,   344°
Below 10°   06:57:40 10° N,       2°
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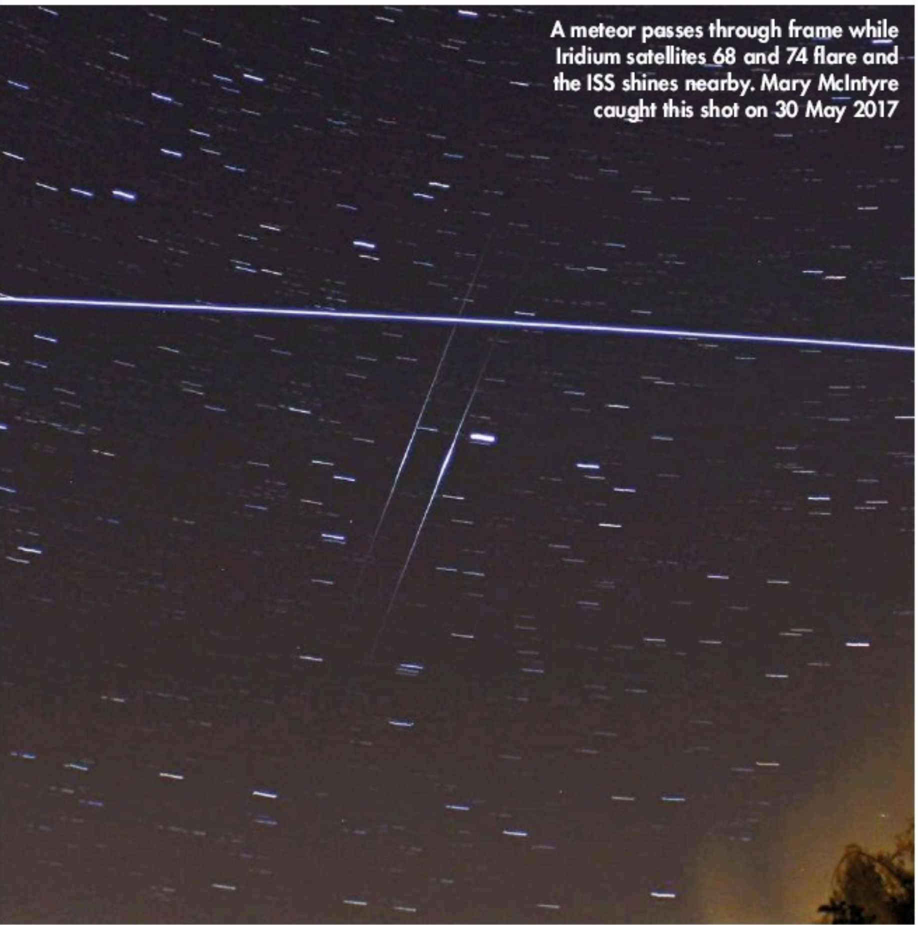
◂ **The free iOS and Android app Heavens-Above provides comprehensive tracking information for Iridium satellites**

The new Iridium NEXT satellites use a design that doesn't flare, much to the disappointment of avid flare hunters

> "I went outside and saw my satellite go across the sky. It was a fantastic sight and I got emotional about it"
> Matt Desch



A meteor passes through frame while Iridium satellites 68 and 74 flare and the ISS shines nearby. Mary McIntyre caught this shot on 30 May 2017

satellites, a process that involves de-orbiting all of its older hardware.

"As we continue to launch, we'll continue to de-orbit," says Matt Desch, CEO of Iridium Communications. "The final launch will be in June 2018 and by the fall of 2018 we won't need any more of the original satellites, so the last one to predictably flare will be around the end of 2018."

That news has caused something of a rush among flare-hunters to complete their observations before the old fleet burns up in the atmosphere. "I so badly want to photograph the entire Iridium network, it's become quite an obsession," says Mary McIntyre, an amateur astronomer who's been observing the satellites for about seven years from her garden observatory in Oxfordshire. She only has eight to go to get the set. "I'm gutted that the new Iridium satellites won't flare; it's going to be really sad," she says.

More function, less flare

The current fleet of Iridium satellites provides voice and data coverage to satellite phones and transceivers around the globe from a near polar orbit, at an altitude of 786km and an inclination of 86°. They've been operating since May 1997. ▸

MARY MACINTYRE X 3, IRIDIUM PHOTO, IRIDIUM COMMUNICATIONS INC, ISTOCK

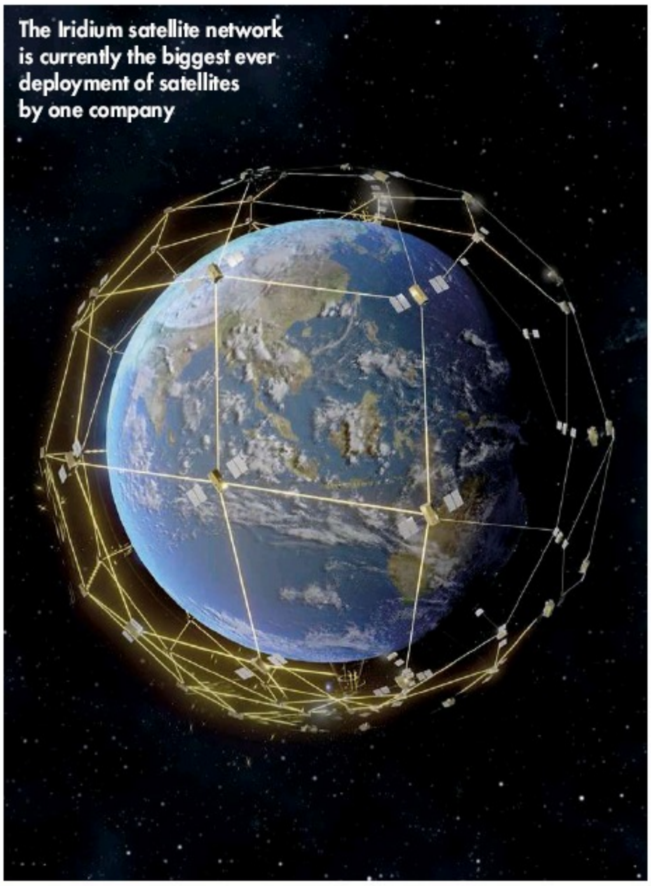
▲ Nikki Young caught the moment when two Iridium satellites cross paths, producing a double flare

▸ The new fleet of Iridium NEXT satellites are being launched to bring new services online such as Iridium Certus (a 1.4Mbps broadband connection for the entire planet) and Iridum Aireon (an aircraft surveillance and flight tracking network) but they have a flat bottom and a phased array antenna, so they don't flare. "When we chose the new, more efficient design, we realised they wouldn't flare, which was a bit disappointing because we feel the same way as the enthusiasts do," says Desch, who recalls hearing reports of flares from the original Iridium satellites shortly after their launch. "I was in North Carolina and I computed exactly where a flare was going to occur, then went outside and saw my satellite go across the sky. It was a fantastic sight and I got emotional about it."

Iridium flares aren't easy to spot, however. At least, not without first doing some research. And they shouldn't be confused with the steadily bright International Space Station, which can be seen from the whole of the UK. "The flares are very location-specific because their reflective panels are so small," explains McIntyre. "The viewing track is about 70km wide and if you look on www.heavens-above.com it'll tell you exactly how far you are from the flare centre. If it's faint, you know you're near the limit." McIntyre also recommends an app called SatTrack, which not only gives the orbital path of each Iridium satellite, but also provides an exact alt azimuth position, alongside a countdown to the nearest second of when the flare will peak.

Although Iridium is committed to de-orbiting its entire fleet to minimise space junk and the majority will be gone by the end of 2018, all is not completely lost for flare-hunters. "You might see some tumbling flares for a period of time into 2019 and some of the satellites might take as long as 20 years to come down," says Desch. Either way, the predictable yet fleeting wax and wane of an Iridium flare will soon be consigned to stargazing history. Ⓢ

Follow the end of the Iridium era with the hashtag #flarewell on Twitter, and share your images with us @skyatnightmag



The Iridium satellite network is currently the biggest ever deployment of satellites by one company

We need to talk about SPACE JUNK

Orbiting satellites enable us to stay connected 24 hours a day, but can also cause major problems

There's an estimated 7,500 tonnes of hardware currently orbiting Earth. Does the intense schedule of Iridium NEXT satellite launches just add to the problem of space junk? Yes and no. The Iridium constellation's original owner Motorola put 95 satellites in orbit during 1997 and 1998, but many failed. "There were a few out-of-the-box failures, some de-orbited quickly, but there are still some tumbling satellites up there now," says Matt Desch, CEO of Iridium Communications.

If that sounds dangerous, it's because it is. In 2009, Iridium Communications lost a satellite when it collided with Kosmos-2251, a defunct Soviet satellite, over northern Siberia. The US Space Surveillance Network still tracks the debris of that event. There are thought to be around two dozen Iridium 'tumblers' and many of them could be up there for 20 years. But Iridium Communications is taking responsibility for clearing up after itself by deorbiting old satellites. "Our goal has always been to deal with everything that we can as quickly as we can and it's a commitment we are honouring," says Desch.

The original 95-strong Iridium constellation was the biggest ever deployment of satellites by one company, but there are two bigger global high-speed satellite internet constellations planned. OneWeb is proposing to launch 900 satellites while SpaceX is planning 4,425. In other words, the problem of space debris – which includes rocket upper stages and mission-related objects, not just defunct satellites – is not going to go away any time soon.

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What the Universe's most sudden – and violent – events can tell us

A supernova detonation occurs when a star's core can no longer resist the force of its own gravity

ISTOCK, PAUL WOOTTON X 4, EUROPEAN SPACE AGENCY AND JUSTYN R. MAUND (UNIVERSITY OF CAMBRIDGE)

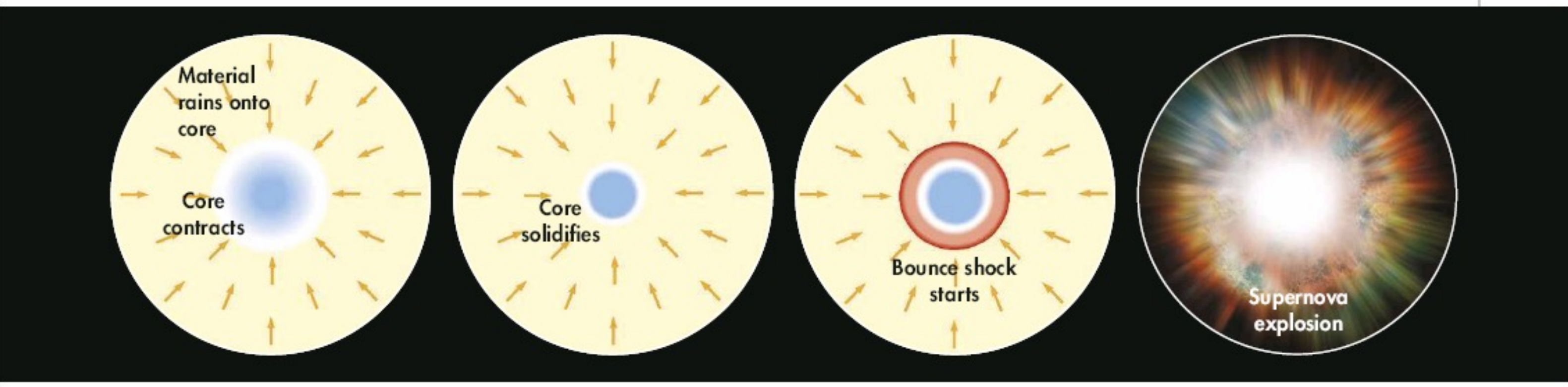
When large stars begin their death throes they explode in a colossal supernova, one of the most sudden and violent events in the sky.

Large stars live fast and die young. They, like stars of all sizes, create light by converting hydrogen to helium in a process known as nuclear fusion. But in the most massive stars this process is rapidly accelerated, meaning that they can burn through their stores of hydrogen gas within as little as a few million years. Compare this to the Sun, which has a lifespan estimated to be 10 billion years.

Stars live in a delicate balance between two opposing forces: the gravity trying to make them collapse inwards and the thermal pressure of nuclear fusion exerting an outward pressure. As the hydrogen in the core gets used up, the star begins to convert helium into heavier and heavier elements; at first lithium and oxygen, before working all the way up the periodic table to iron. Not only do these heavier elements cause the core to become more dense – increasing its gravitational pull – but the fusion reactions also release less energy to balance this out. Eventually all that the star has to act against gravity is electron degeneracy pressure – the resistance to having more than one electron in the same place at the same time.

When the core reaches a critical density of 1.4 solar masses, known as the Chandrasekhar limit, even the plucky electrons can't keep up the fight. At that point the star's core collapses in a matter of seconds, quickly followed by the outer layers of gas rushing in at as fast as 25 per cent the speed of light.

The core continues to collapse until the resistance between atomic particles stops it from collapsing any further. All the atomic nuclei are tightly packed together by now, creating a solid surface. Normally, this tightly packed ball remains as a neutron star, but if the core is massive enough then it may continue to collapse even further, creating a black hole.



▲ When a star's core becomes so dense that it can no longer contract, the material still collapsing onto it rebounds and sets off the supernova

Meanwhile, the gas that was rushing in at incredible speeds strikes against the now solid surface of the neutron star and rebounds in a massive shockwave that ends in a huge explosion – the supernova.

Looking for the light

These stellar detonations create a huge amount of light for a short amount of time. On Earth, researchers hoping to study these fleeting but fiery events have to look out for points of light that suddenly appear in the night sky. Originally this was done by eye, and some amateur astronomers still search for supernovae at the eyepiece, but most professional supernova surveys nowadays use automated systems to image the sky, searching for 'stars' that weren't there the night before.

Not everything they find is an exploding star, however. Some explosions are dimmer nova, where the interaction between a pair of stars causes one to temporarily flare up. And in August 2017, researchers observed a kilonova for the first time, a much brighter explosion caused by the collision between two neutron stars. These are thought to be the origin of all naturally occurring elements heavier than iron.

To uncover what kind of nova an explosion might be, researchers have to watch how the light from the bright, new object changes. But they need to be quick. After the explosion the light quickly fades from view, so once a new supernova is found astronomers immediately notify all the telescopes in the world that might be able to observe the star. Together they take brightness measurements across every possible wavelength and use spectroscopy to pick out which elements were present in the star when it exploded.

These elements don't just disperse into the Universe, but instead form a type of nebula called a supernova remnant. These nebulae are rich in hydrogen gas, which clumps together to form the next generation of stars. Meanwhile, the heavy elements coalesce together, eventually forming planetary systems around the stars in the nebula. By studying supernova, researchers not only grow to understand the life cycles of these massive stars, but also the origins of the planets too. S

ELIZABETH PEARSON is an astrophysicist and *BBC Sky at Night Magazine*'s news editor

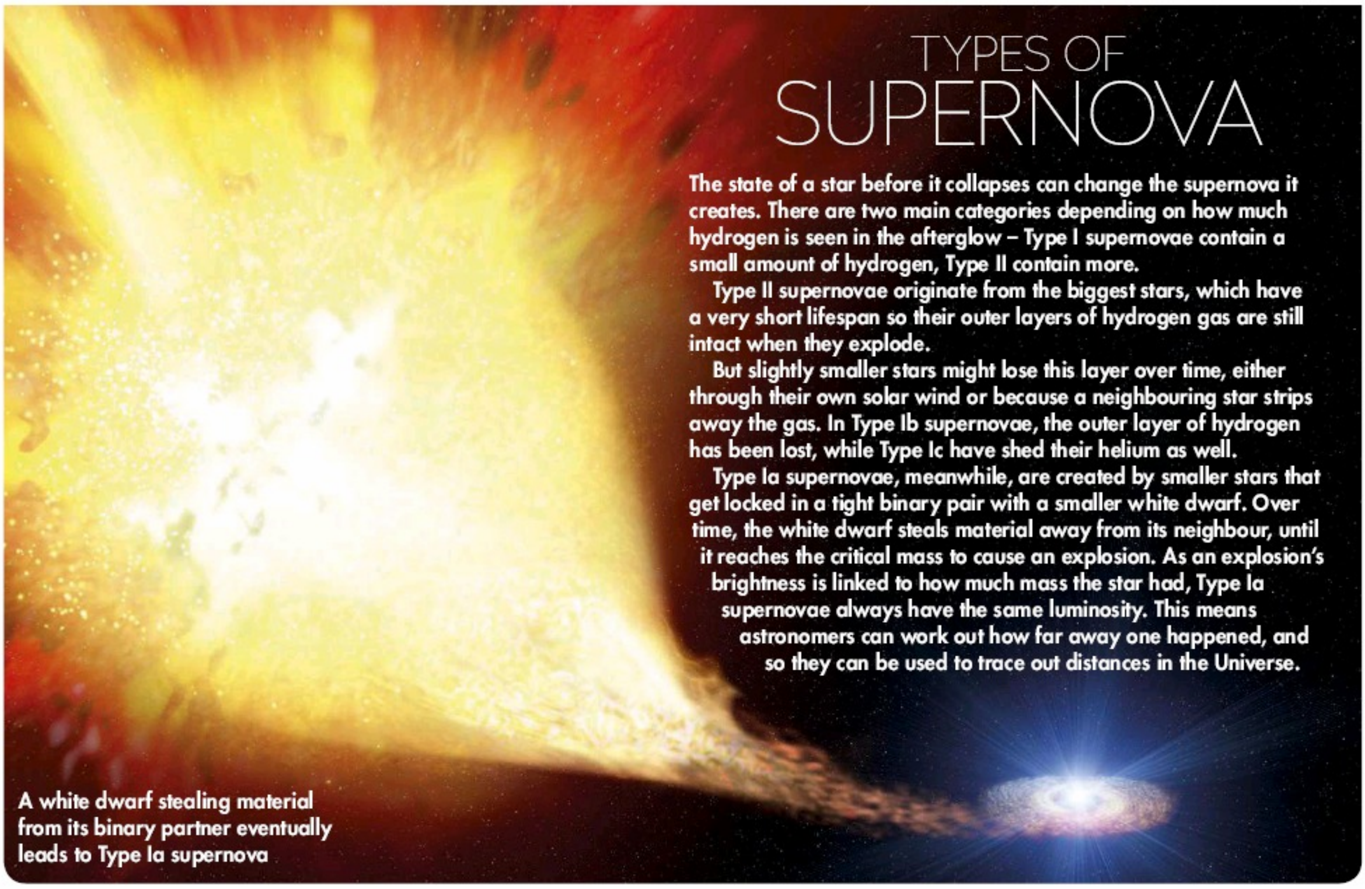
TYPES OF SUPERNOVA

The state of a star before it collapses can change the supernova it creates. There are two main categories depending on how much hydrogen is seen in the afterglow – Type I supernovae contain a small amount of hydrogen, Type II contain more.

Type II supernovae originate from the biggest stars, which have a very short lifespan so their outer layers of hydrogen gas are still intact when they explode.

But slightly smaller stars might lose this layer over time, either through their own solar wind or because a neighbouring star strips away the gas. In Type Ib supernovae, the outer layer of hydrogen has been lost, while Type Ic have shed their helium as well.

Type Ia supernovae, meanwhile, are created by smaller stars that get locked in a tight binary pair with a smaller white dwarf. Over time, the white dwarf steals material away from its neighbour, until it reaches the critical mass to cause an explosion. As an explosion's brightness is linked to how much mass the star had, Type Ia supernovae always have the same luminosity. This means astronomers can work out how far away one happened, and so they can be used to trace out distances in the Universe.



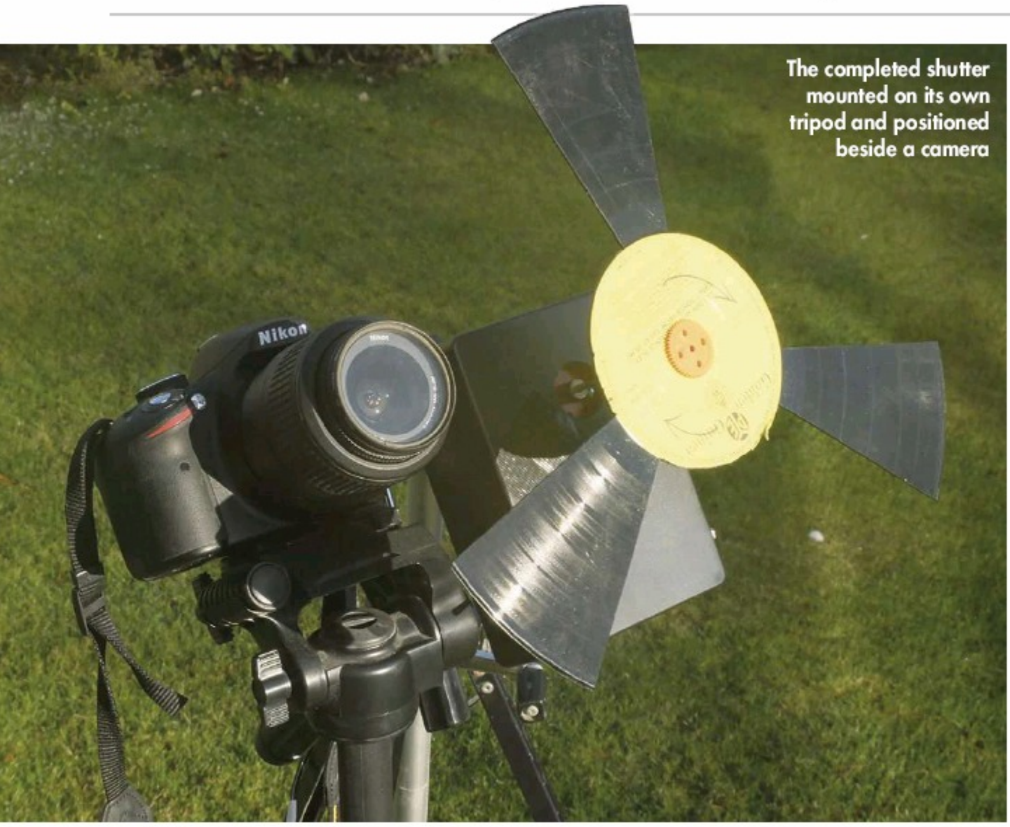
A white dwarf stealing material from its binary partner eventually leads to Type Ia supernova

How to...

With **Mark Parrish**

Build a rotating meteor shutter

Get more info from your meteor images with this simple device



The completed shutter mounted on its own tripod and positioned beside a camera

This month we're showing you how to build a rotating shutter to enable you to capture images that depict a meteor's movement as well as potentially yield some interesting scientific information.

Meteor observations involve keeping a careful record of position, direction and rate of any meteors you see. Photographs supplement these records, particularly as cameras record accurate times in their image data. Some meteor photographers also enhance their images by employing rotating shutters – devices that rapidly block and unblock the lens but have no obvious effect on background stars in the image.

If a bright, fast-moving meteor passes through the camera's field of view while the rotating shutter is interrupting it, the meteor's trail appears as a broken, rather than continuous, line. By counting the number of segments the trail is split into it's possible to tell how far the meteor travelled across the sky in the background – its angular velocity – during a known period of time, provided you know the speed of the shutter's rotation.

This isn't the meteor's actual speed, as it's falling downwards and its height is unknown. But if the same meteor is captured from two locations it's possible to determine its speed using triangulation. While single captures can't determine a meteor's speed, if the length of the trail sections varies in the image, that's an indication of deceleration. It's also possible to examine variation in light intensity and colour along the trail.

The control unit

Traditionally, rotating shutters rely on electricity from the mains to make them spin at a predictable speed. Synchronous motors rotate according to supply frequency, but mains power isn't desirable in this instance, and isn't available in remote locations, so we've designed our shutter to work from a 12V powertank.

TOOLS AND MATERIALS

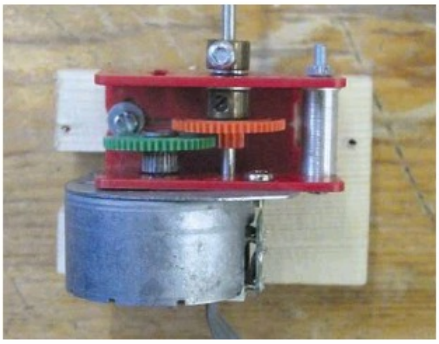
TOOLS
Hacksaw, drill and drill bits (for small holes in the project casing), soldering iron, screwdrivers

MATERIALS
Arduino Uno (Rev 3) prototyping platform, small breadboard, SPST toggle switch, small 12V Stepper motor, plastic gearbox with a 4:1 ratio (or build your own with Meccano), L293D motor controller

SUNDRIES
Plastic project casing (150x100x55mm min), jump wires, unwanted 12-inch vinyl record or thin card, 1/4inch-20 nut (or other suitable tripod fixing method), 5mm OD male barrel jack, cigarette lighter-style cable/plug to suit your powertank, offcuts of wood/small screws for mounting gearbox

To generate consistent output speeds we've used a stepper motor, which rotates in a series of small steps. You can find them in old photocopiers but new stepper motors are cheap to buy and available from high-street electronics shops. When a pulse of electricity is sent to the correct motor coils it moves one step, so a steady stream of pulses will turn it at exactly the desired speed. To generate these pulses we've used an Arduino prototyping board (a small microprocessor). These can be programmed to do a wide variety of tasks, including this one.

ALL PICTURES: MARK PARRISH



▲ Your gearbox should convert one turn of the motor into four turns of the output shaft

Stepper motors don't like running fast so we've used two gears to speed up the revolution of the rotor, in this case an old vinyl record with three vanes cut into it (feel free to experiment with other light materials and designs for your rotor).

In use, the shutter device should be mounted on a separate tripod to avoid it transmitting vibrations to the camera, but positioned so that its vanes pass in front of the camera lens. Give the rotor a spin to get it up to speed and then switch the shutter on, the motor will then keep it spinning.

The control unit

There's no need to learn any programming as we've created all the code for you. This code is easily customised to suit different motors, rotor designs and output speeds. You simply have to upload the code to the Arduino using a USB cable, then see how it performs. The Arduino 'remembers' the last code you sent it and will work without a computer the next time you switch it on.

This is definitely a project for people who like to experiment but should yield good results if you're patient. You can download all the necessary diagrams and program code from www.skyatnight magazine.com/bonuscontent.

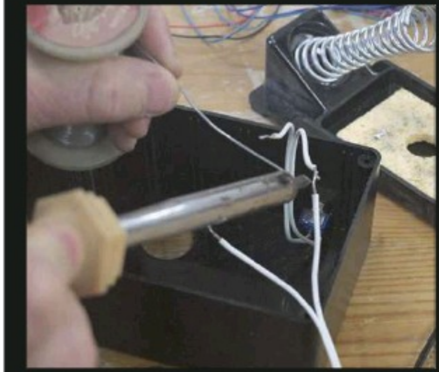
The motor mounting and gear drive, along with adaptations of the code are all areas for possible development if you wish to keep experimenting with the design. If you want a setup that can provide full-sky coverage it might be possible to adapt the design to work with the multi-camera platfrom from the July 2016 issue. S

Mark Parrish is a consummate craftsman. See more of his work at buttondesign.co.uk

YOUR BONUS CONTENT

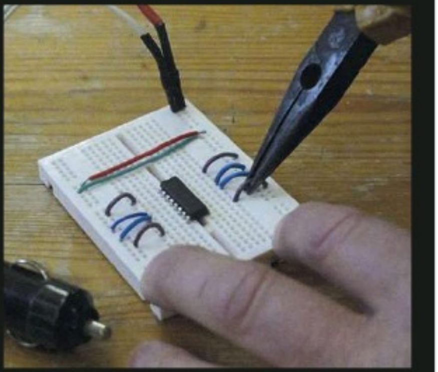
Download the diagrams and code to build the rotating meteor shutter

STEP BY STEP



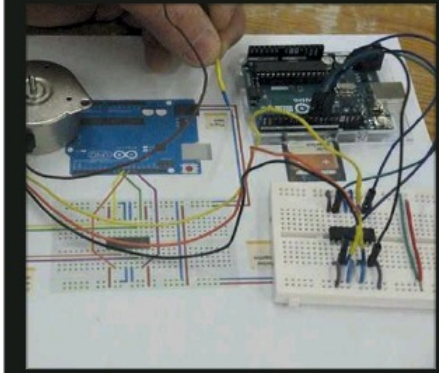
STEP 1

Use twin-core cable to make a power lead. Attach a plug for the powertank, then split the other end and solder the positive to one terminal of the toggle switch and a short wire to the other terminal. Solder short wires to the terminals of the barrel plug.



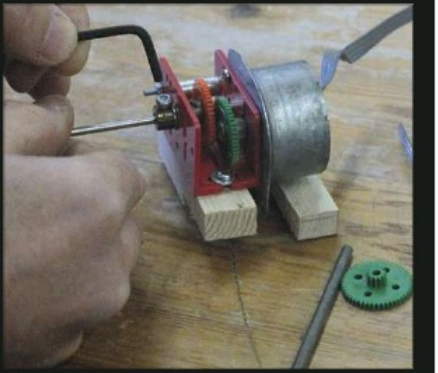
STEP 2

Mount the L293D controller on the breadboard as per the diagram in the Bonus Content. Use the wires coming from the toggle switch to make power connections to the breadboard. Use short jump wires to connect the power to the controller.



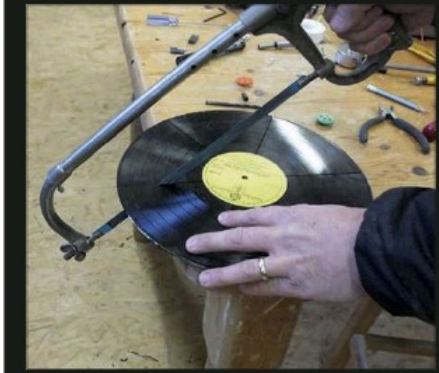
STEP 3

Connect the Arduino power cable to the breadboard. Use jump wires to connect the Arduino to the controller and the controller to the motor. Refer to the diagram in bonus content and motor specification for correct connection to trigger the wires in sequence.



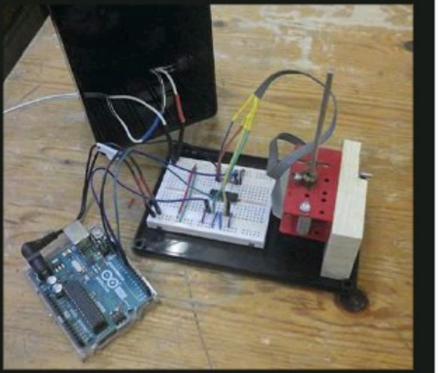
STEP 4

Build your gearbox kit so that one revolution of the motor produces four turns of the output shaft. Use an offcut of wood to support the motor and gearbox in the case. Download the code, modify it if needed and upload it to the Arduino, then test the circuit.



STEP 5

Mark out the record with two, three or four equal vanes and gaps in between but leave a wide central section. Carefully cut out the vanes (use a hacksaw if you're cutting vinyl). Use a spare gear to make a mounting boss and glue it over central hole.



STEP 6

Mount the motor and gearbox inside the lid so the shaft extends out of it. Drill holes for the switch, cable and mounting nut, which you can glue into place. Use Velcro to fix the breadboard and Arduino inside the casing. Fix the rotor to the shaft for the final touch.

Image PROCESSING

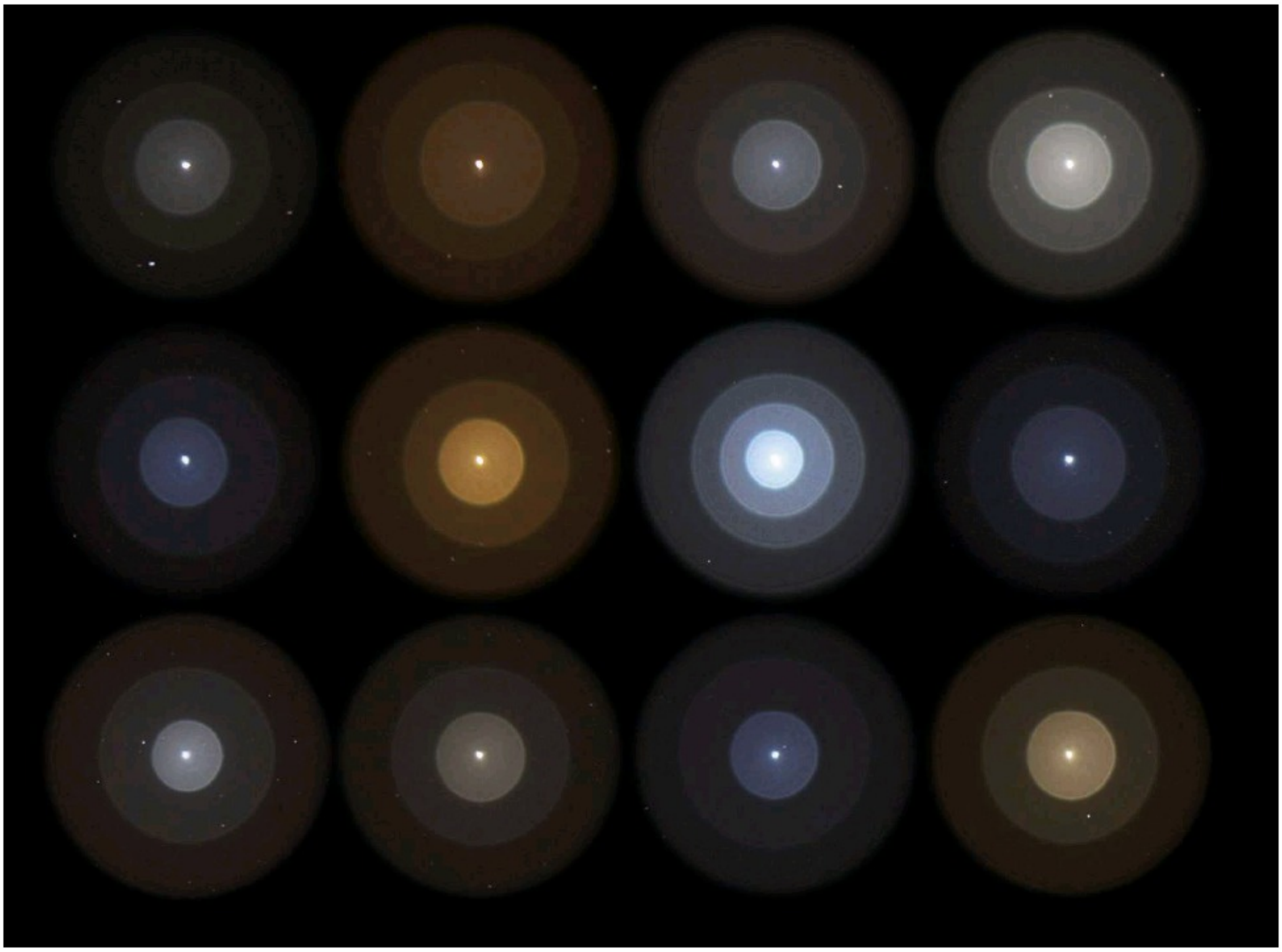
With
Steve Brown

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

Advice from 2016's Stars and Nebulae category winner

IAPY masterclass:
Colours of the Winter Stars

Learn the trick to catching subtle shades of stars and the halos around them



▲ Every colour but white: stars pictured from left to right, top row to bottom row, are Polaris, Aldebaran, Rigel, Capella, Bellatrix, Betelgeuse, Sirius, Castor, Procyon, Pollux, Regulus and Arcturus. This technique really brings out the colour differences between these stars

ALL PICTURES: STEVE BROWN

Ask a casual observer of the night sky what colour the stars are and they'll probably say "white". On closer inspection, however, the stars display a range of colours, from white to blue and orange to red. A close look at many of the constellations visible during the winter months in the northern hemisphere will reveal stars ranging from blue-white to deep orange in colour. A typical image of these stars will show only the most obvious colour differences, but we can bring out the colours of the brightest ones with some unusual astrophotography techniques.

To bring out the colour of each star we're going to adjust the focus of the lens over the course of a long exposure. A typical in-focus, short exposure shot of a star will show it as a white point, with perhaps some colour around the edge. This is because the star is a point source of light and this tends to oversaturate the pixels on the camera sensor, resulting in a white image, with some colour around the edge as surrounding pixels pick up some of the light but not enough to become saturated. By capturing the star out of focus its light is spread over a larger area of the sensor, which avoids oversaturation of each pixel and preserves the colour information.

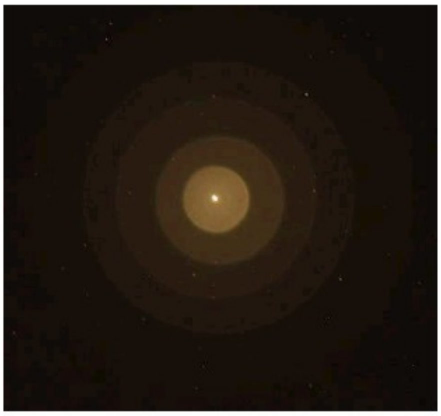
To capture a large enough image of a star, use a DSLR camera with a lens that has a focal length of at least 200mm. Use a low ISO setting to capture a greater tonal range; 100-400 should produce good results. A tracking mount will keep the star in the centre of the frame as you take the shot and a remote shutter release cable will avoid camera shake.

Ensure that your chosen star is as close to the centre of the frame as possible. If the star is off-centre then you'll see a deformed final image. Use the 'bulb' setting on your camera to control how long the shutter is open for. To get yourself and your kit ready for the shot use one hand to operate the remote shutter release cable and the other to turn the focus ring of the lens.

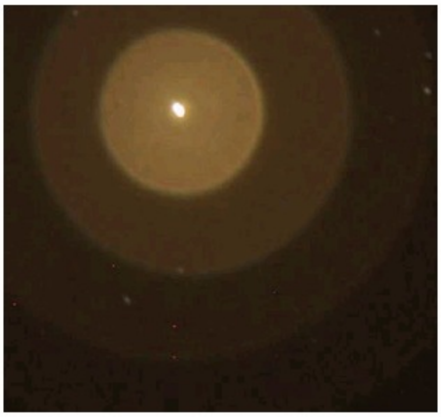
Slow and gentle

As you'll be moving it yourself, ensure that the focus setting of the lens is set to 'manual'. Press the button to open the shutter and start taking the picture. Leave the camera to capture an image of the star for a few seconds. This will give a good exposure of the star to form the centre of the image.

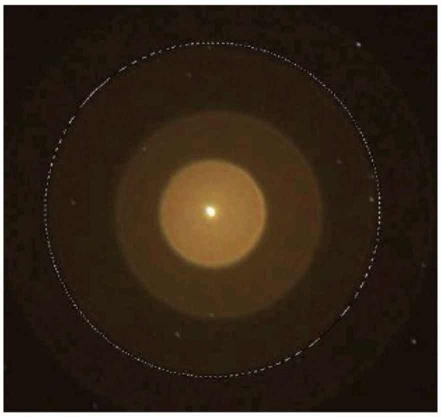
Next, very gently turn the focus ring a little over the course of two to three seconds. It's important to do this with as little vibration as possible – any movement of the camera will result in an off-centre image, which won't look as good. Leave the focus at this new point for around 10 seconds. Repeat the process of turning the focus ring and waiting for 10 seconds for around one minute.



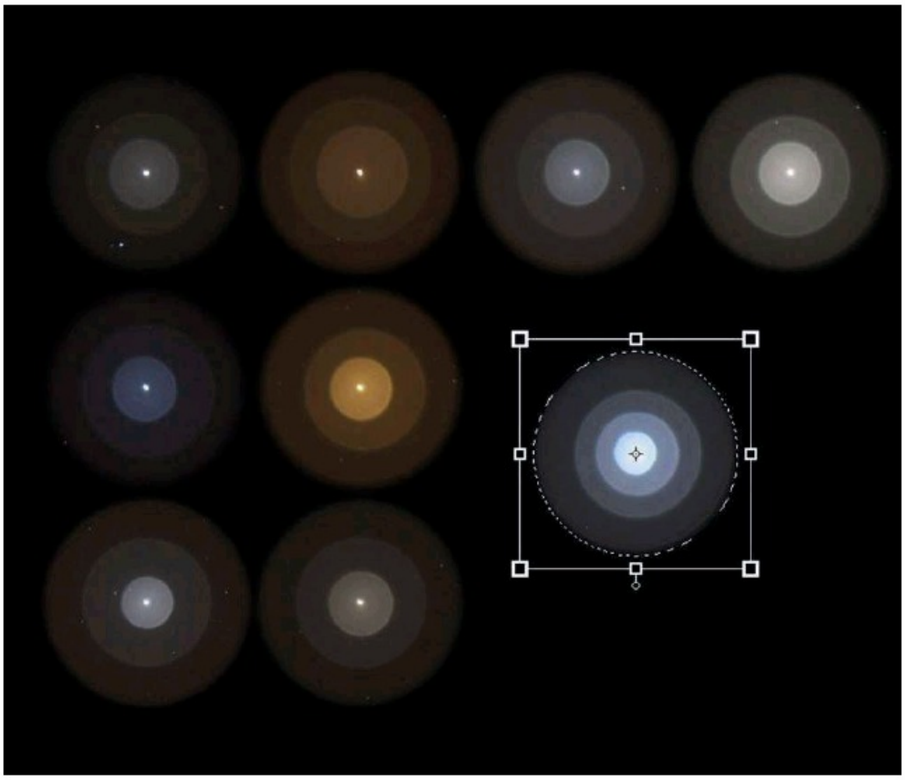
▲ The orange light of Betelgeuse can be clearly seen in this initial capture of the star



▲ Use image-processing software to correct blemishes, dust and hot pixels on the image



▲ Select and feather the image to keep only the central star and prominent colour rings



▲ Assembling the final image: align each captured star image into a final composite picture

After the minute is up release the shutter button to close the shutter. You can then review the image on your camera's screen and try again if you're not happy with the result. A good shot should look like the picture to the left.

Now import the images into a graphics program for processing. The first thing to do is remove any hot pixels, dust marks and other blemishes from the star image. Use your program's healing brush tool to remove these.

Next, use the circular selection tool to select the star image and the boldest three or four of the surrounding colour discs. Add a substantial feather to the selection to ensure that the edge blends well with the background of the final composite image. A setting of around 50 is good here. The aim with this processing is to get a perfect circular image with faded edges and no blemishes within the coloured discs. Do this for each image you've captured.

Next, create a blank image with a black background. This should be large enough to contain all of your final star images. Copy and paste each image into a new layer. You can then move each one around to line them up.

Finally, flatten the image for the end result, which in this case, was shortlisted in the Stars and Nebulae category of the Insight Astronomy Photographer of the Year awards 2017. Ⓢ

STEVE BROWN is an astrophotographer and won the Stars and Nebulae category in 2016's IAPY awards

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Scope DOCTOR

With **Steve Richards**

Our equipment specialist cures your optical ailments and technical maladies

▲ A city such as San Juan would be a challenging environment to observe in, although an 8-inch SCT will help you cut through some of the light pollution

I live in San Juan, Puerto Rico and would like to observe from my ninth-floor balcony. Can you recommend a telescope for a city environment?

JOSÉ JUAN TERRASA-SOLER

There are two main types of light pollution: sky glow and local source. Sky glow is the orange glow caused by the many light sources in a city; local source is light from, say, a single streetlight or a neighbour's house.

Your choice of telescope should be based on the same criteria that you'd use for a dark observing site. A large aperture instrument will collect more starlight than a small aperture regardless of the ambient light conditions so it will pay to buy the largest aperture that you can afford. But, in your case, living up on the ninth-floor, this choice needs to be tempered with consideration for storage at your home and carrying the gear to and from your apartment.

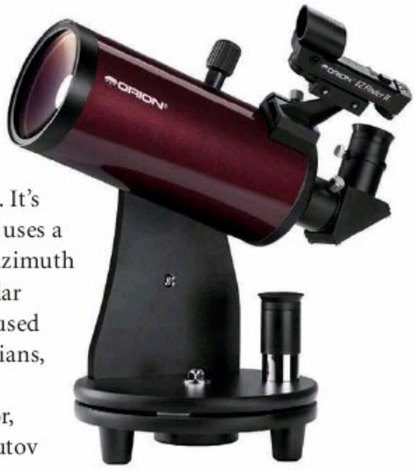
There's a strong argument for buying a Go-To mount as the light pollution in Puerto Rico will make it more difficult to select suitable stars for manual star hopping to celestial objects.

You need to strike a compromise here and an 8-inch Schmidt Cassegrain from either Celestron or Meade, mounted on an altazimuth Go-To mount would give you a good aperture in a compact format. Adding an extended light shield to the front of the telescope would not only reduce the risk of dew but would also help to reduce the interference from local light sources. Also get a good pair of 10x50 binoculars so you can get quick views of the night sky.

ISTOCK, PAUL WHITFIELD, ORION

Can you recommend any bags for an Orion 90mm table-top telescope?

MUHAMMAD F SARWAR



▲ A cabin bag is a possible luggage option for this Orion scope in lieu of a dedicated carry case

Your Orion 90mm TableTop telescope is an interesting variation on the 'Dobsonian' theme. It's an instrument that uses a simple wooden altazimuth base, which is similar to that commonly used with small Dobsonians, but instead of a Newtonian reflector, it supports a Maksutov Cassegrain telescope.

Unfortunately, there is no specific bag available for this telescope and the one that Orion USA suggests as a potential fit is not only too long but also unavailable in the UK. Thankfully, there are other solutions available from photographic retailers in the form of large gadget bags and one in particular would appear to fit your requirements well. The Neewer Photo Studio Equipment Trolley Carry Bag has internal dimensions of 77x28x27cm and adjustable partitions so you can customise the interior to suit your telescope while still having plenty of room for accessories. As a lower cost alternative, a soft-sided hand luggage cabin bag may just stretch enough to accommodate the diameter of the base to serve the same purpose.

STEVE'S TOP TIP

What is a Bahtinov mask?

A Bahtinov mask is a specially cut visor made from cardboard or plastic that you place on the front of a telescope to help you focus accurately.

The special shape of the cut-outs in the mask produce a set of diffraction spikes in the same manner as the secondary mirror spider vanes on a Newtonian reflector. However, the Bahtinov mask's diffraction spikes form a very specific shape comprising a cross with a line passing through it. Observing a diffracted bright star with this mask in place and adjusting the focus until the line perfectly bisects the cross ensures that accurate focus is achieved.

Steve Richards is a keen astro imager and an astronomy equipment expert

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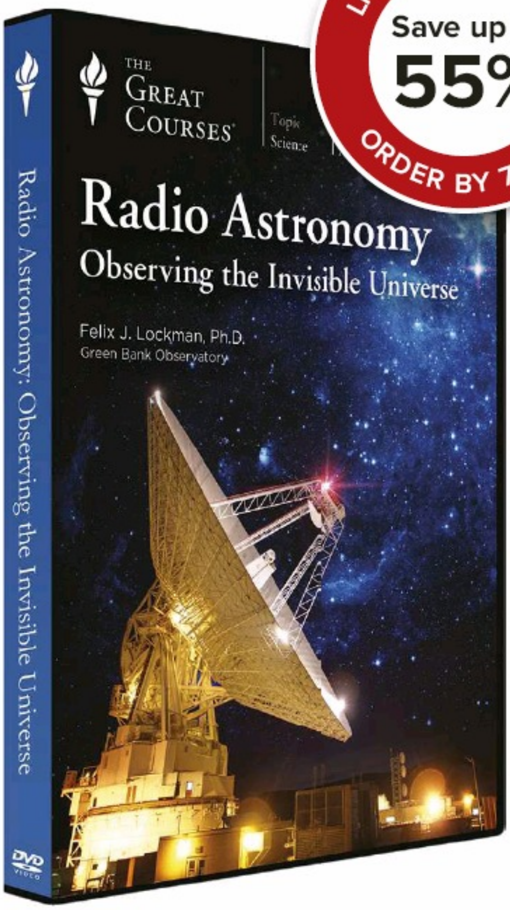

Pull Back the Curtain on the Unseen Universe

For a few hundred thousand years, we used our eyes as our primary astronomical tool. But all that changed in the 1930s when a young engineer named Karl Jansky detected radiation below the visible part of the spectrum emanating from an astronomical object—and radio astronomy was born.

Radio Astronomy: Observing the Invisible Universe takes you on a thrilling journey through astounding discoveries and a virtual tour of the world's most powerful radio telescopes with Felix J. Lockman, Ph.D., of the Green Bank Observatory as your guide. But perhaps the most astounding of all radio astronomy discoveries is this: The dominant molecular structures in interstellar space are based on carbon. That is not what scientists had expected. We have always labeled these molecules "organic" because life on Earth is carbon based. Now we know the chemistry of the entire Milky Way is organic, not just our home planet, and it is likely that any extraterrestrial galactic life would be related to us, at least on the molecular level. Will we find other organic life forms out there? Radio astronomers don't know. But they're certainly working on it.

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Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★☆ Very good
★★★☆☆ Good
★★☆☆☆ Average
★☆☆☆☆ Poor/Avoid

This month's reviews

FIRST LIGHT

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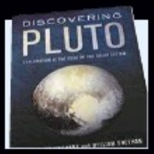

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GEAR

104 Find out about the newest kit, including this Orion Lantern

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www.skyatnightmagazine.com/SWexpl130PS

Sky-Watcher Explorer-130PS telescope & AZ-EQ Avant mount

WORDS: STEVE RICHARDS

Begin your astronomy adventure with this portable and friendly partner

VITAL STATS

- **Price** £249
- **Optics** 130mm parabolic Newtonian reflector
- **Focal Length** 650mm (f/5)
- **Mount** AZ-EQ Avant dual-mode altazimuth/equatorial mount
- **Tripod** Aluminium tripod with 21cm extension tube and accessory tray
- **Extras** Red dot finder, 25mm and 10mm eyepieces, 2.35kg counterweight
- **Weight** 9kg
- **Supplier** Optical Vision Ltd
- **Tel** 01359 244200
- **www.**opticalvision.co.uk

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The continuing problem of light pollution means a telescope that can be easily transported to dark-sky sites instantly has great appeal. And that's exactly the sort of telescope Sky-Watcher's new Explorer-130PS is intended to be. The telescope and its AZ-EQ Avant mount are a compact and light package but the whole setup has also been designed with beginners in mind. Assembly and operation are simple and user friendly in the hopes of providing a welcoming introduction to observing the night sky.

It uses a Newtonian reflector design that employs a parabolic primary mirror to collect and focus the light, and a flat secondary mirror to reflect it to the eyepiece. This design requires collimation to align the two mirrors accurately with one another and the eyepiece. But, to make life easier for beginners, a large chunk of this potentially perplexing process has been removed. The telescope has a fixed mirror cell for the primary mirror, which is collimated at the factory so it'll only require occasional adjustment to the secondary mirror, for which a suitable Allen key is supplied. Upon delivery, the review telescope was in excellent collimation and produced well-formed stars during this test – it really did work well straight out of the box.

SKY SAYS... Quick to assemble, easy to setup and provides great views straight out of the box

Stable and smooth

The mount is just as important as the telescope and Sky-Watcher supplied the new, dual-mode AZ-EQ Avant mount with the Explorer-130PS so we were keen to see how it performed. It didn't disappoint, proving quick to assemble and providing a sturdy platform for the telescope. An accessory tray for your eyepieces also serves as a tripod-leg tensioner to help stabilise the setup.

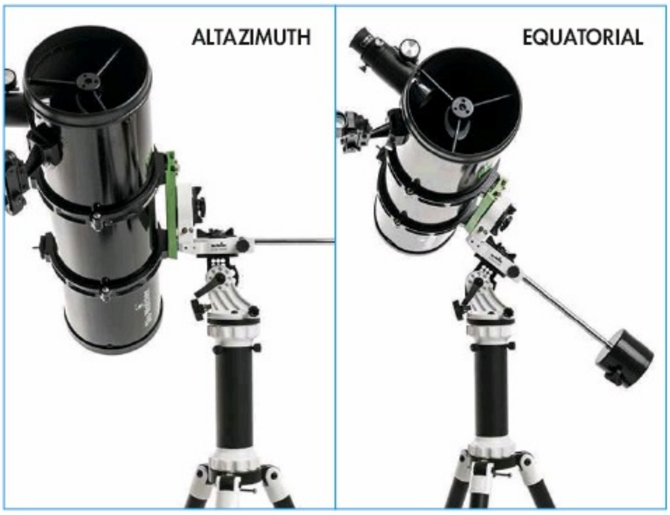
Adjustments in both altazimuth (AZ) and equatorial (EQ) modes are smooth and it's easy to keep objects centred in the field of view. In EQ mode, the altitude adjustment and locking clamp are simple to use although, with no method of installing a polarscope, polar alignment consists ▸

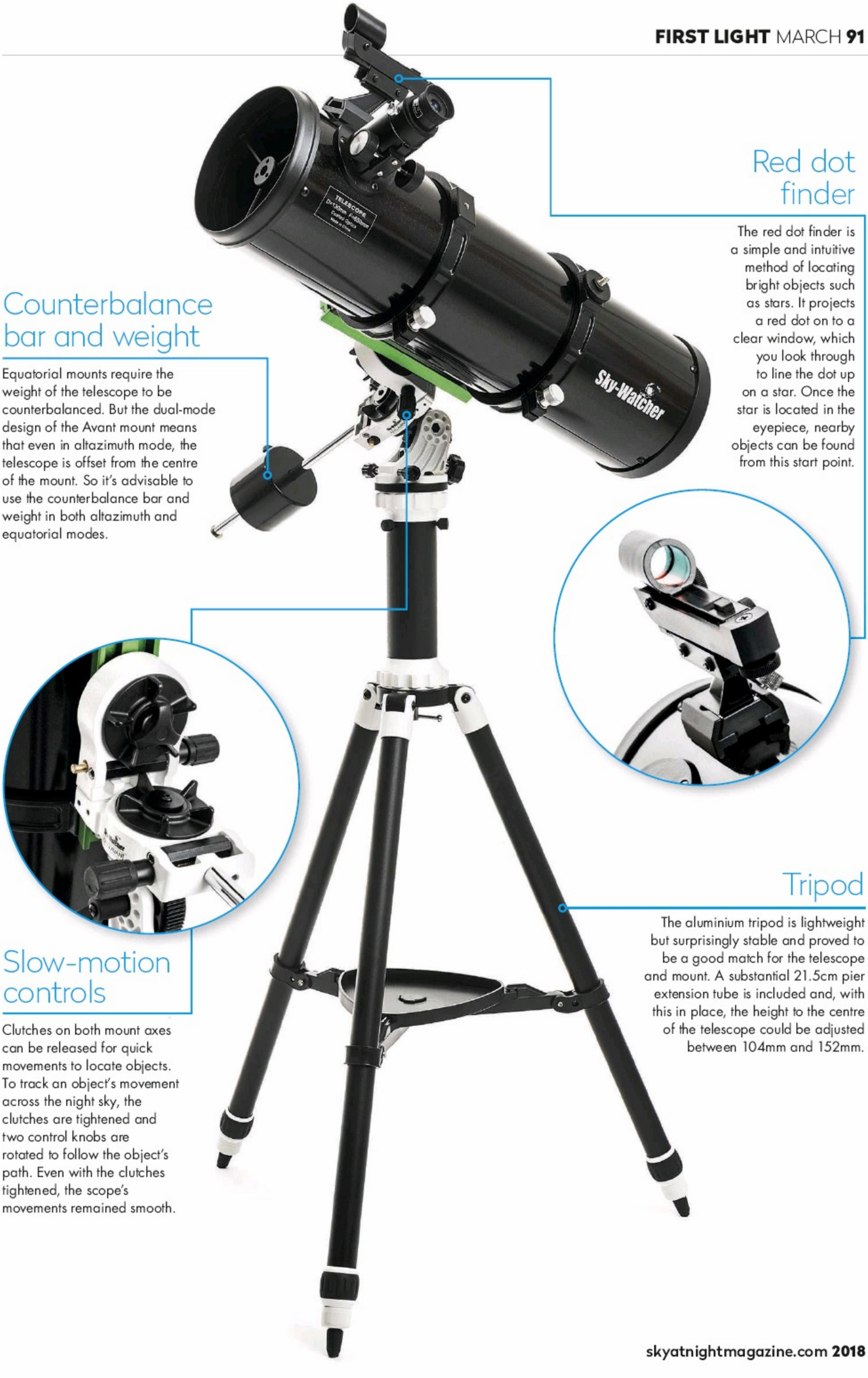
Two mounts in one

Although at first glance the AZ-EQ Avant mount looks like a conventional altazimuth mount, it can actually be used in two modes.

In altazimuth (AZ) mode, the mount moves horizontally in a 360° circle (azimuth) and vertically (altitude) from the horizon to the zenith, the point in the sky immediately above the observer. This makes it simple to locate astronomical targets. But to follow these objects as they move across the night sky in an arc it's necessary to make adjustments in both altitude and azimuth axes.

In equatorial (EQ) mode, the whole mount head is tilted on an adjustable wedge so that it points to the North Celestial Pole (in the northern hemisphere) or South Celestial Pole (in the southern hemisphere), around which the sky appears to rotate. This means that once you've aligned the telescope on an object using the 'horizontal' adjustment (right ascension – RA) and the 'vertical' adjustment (declination – Dec.), it's only necessary to make adjustments in the RA plane to follow the object as it traverses the sky.





Red dot finder

The red dot finder is a simple and intuitive method of locating bright objects such as stars. It projects a red dot on to a clear window, which you look through to line the dot up on a star. Once the star is located in the eyepiece, nearby objects can be found from this start point.

Counterbalance bar and weight

Equatorial mounts require the weight of the telescope to be counterbalanced. But the dual-mode design of the Avant mount means that even in altazimuth mode, the telescope is offset from the centre of the mount. So it's advisable to use the counterbalance bar and weight in both altazimuth and equatorial modes.

Slow-motion controls

Clutches on both mount axes can be released for quick movements to locate objects. To track an object's movement across the night sky, the clutches are tightened and two control knobs are rotated to follow the object's path. Even with the clutches tightened, the scope's movements remained smooth.

Tripod

The aluminium tripod is lightweight but surprisingly stable and proved to be a good match for the telescope and mount. A substantial 21.5cm pier extension tube is included and, with this in place, the height to the centre of the telescope could be adjusted between 104mm and 152mm.

FIRST **LIGHT**

▸ of sighting Polaris, the 'North Star', down the side of the optical tube with the counterbalance bar pointing downwards and towards the north. But this is more than adequate for general observing purposes. The Explorer-130PS also comes with a pier extension to keep the telescope from clipping the tripod legs while slewing and this got a lot of use throughout the review period.

The 130mm-aperture, steel optical tube is finished in a high-gloss black with a silver-flecked finish and is cradled in two substantial felt-lined tube rings, which are attached to a Vixen-style dovetail bar. Surprisingly, the dovetail bar feature isn't used to attach the telescope to the mount. Instead, a 1/4in-20 bolt on the mount is screwed into a matching threaded hole in the base of the bar. In use, this proved to be more than adequate for the purpose and no slippage was experienced during our tests.

A rather basic, plastic, single-speed rack and pinion focuser completes the optical tube but despite some initial reservations we found this to be effective in use. With it we were able to achieve focus quickly and easily.

The supplied red dot finder is an excellent choice, especially for beginners, as it's so easy and intuitive to use. We relied on it extensively for star hopping to various deep-sky objects.

Simple but effective

The telescope's focal length of 650mm is a good compromise for observing a wide range of objects, including both Solar System and deep-sky targets. We enjoyed some excellent views of M27, the Dumbbell Nebula, and M15 in Pegasus very early in the evening, then the Pleiades and the Hyades star clusters and M42 later during the night. In both the 25mm and 10mm eyepieces the waxing gibbous Moon after Christmas was a wonderful sight through this telescope and would easily produce that wow factor for a beginner.

We really liked this scope and mount package. It's simple to assemble, easy to use and gives good views of some of the most popular targets. The mount is very well thought out, light yet sturdy and the complete setup is very appealing.

Verdict

Assembly	★★★★½
Build and design	★★★★☆
Ease of use	★★★★½
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

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Eyepieces

The Explorer-130PS is supplied with 25mm and 10mm eyepieces providing magnifications of 26x and 65x respectively. These are ideal for a beginner, with the 25mm being the better of the two. The 25mm has generous eye relief, making it suitable for spectacle wearers. Both have fold-up rubber eyecups.

SKY SAYS...
Now add these:

1. Lunar/planetary filter set
2. Red-light torch
3. 2x deluxe Barlow

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See an interactive 360° model of these binos at
www.skyatnightmagazine.com/canon1432bin

Canon 14x32 IS binoculars

WORDS: STEPHEN TONKIN

Tame your trembling arms to guarantee smooth views with Canon's image-stabilising binoculars

SKY SAYS...
Smooth, shudder-free views come as standard with Canon's new binoculars

VITAL STATS

- **Price** £1,399.99
- **Optics** 'Super-Spectra' multi-coated
- **Aperture** 32mm
- **Magnification** 14x
- **Prisms** Porro Type II
- **Angular Field of View** 4.3°
- **Focusing** Centre focus, moving internal lens group
- **Eye relief** 14.5mm
- **Interpupillary distance** 55-75mm
- **Weight** 775g
- **Supplier** Canon
- **www.canon.co.uk**
- **Tel** 020 8588 8000

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Canon's new range of image-stabiliser (IS) binoculars is the first to incorporate the lens-shift system that the company uses in its EF camera lenses. In theory, this should give an improvement over the previously used Vari-Angle Prism system of stabilisation, but does it deliver in practice? We tested Canon's 14x32 IS binoculars to see how well the new system works on the night sky.

The binoculars come in a soft, well-padded Cordura case and have a 30mm-wide neck strap that we found to be very comfortable, even against a bare neck. There are no caps for the objective lenses but the dual eyepiece caps fit very well and are tethered to the neck strap by a short cord. There's also a comprehensive instruction manual provided in PDF format on a USB memory stick.

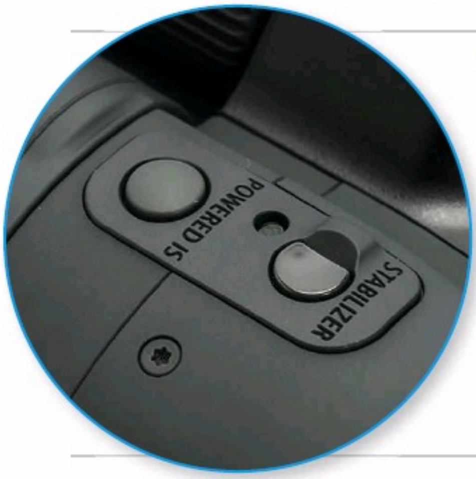
The binoculars are covered with a matte rubber armour that provides a secure grip, even when the binoculars are dew-dampened (although they're not waterproof), and offers some impact protection. There's a rubber bumper around each objective lens to reduce the effects of front-end impacts.

The prism system is a Porro Type II, so you have to rotate the eyepiece turrets to adjust the interpupillary distance. They, and the right eyepiece dioptre adjustment, move smoothly, with enough resistance to ensure that they won't accidentally slip once they've been set. The centre focus also has an action that's light and smooth, with no perceptible backlash.

Lenses and light control

The eye-cups fold down to 3mm above the surface of the lenses, so only 11.5mm of the specified 14.5mm eye relief is available. As a consequence, we were unable to see the entire 4.3° field of view when wearing spectacles. But the focal range of the binoculars extends several dioptres 'beyond' infinity, so most people with any sort of vision impairment should be able to focus the binoculars and observe without spectacles. We found that the 2.3mm exit pupil is small enough to significantly reduce, but not completely eliminate, the effect of mild astigmatism.

When we shone a bright light into the objective lens there was only a tiny amount of light reflected from its surface and the components inside, which suggests that Canon's proprietary Super-Spectra anti-reflective multi-coatings are effective. The binoculars' control of stray light is excellent: there were no spurious ghost images when the lunar terminator was held near the edge of the field of ▸



Versatile image stabilisation

There are two different stabilisation modes, labelled 'Stabiliser' and 'Powered IS'. When you're panning the sky, you use the Stabiliser mode, which eliminates shake, but doesn't try to oppose large movements. When you find your target, you switch to Powered IS mode, which compensates for both kinds of motion. The combination of a sensitive two-axis gyro sensor and fast electronics means that stabilisation is almost instantaneous when you press either stabilisation button. The stabilisation system compensates for motion amplitude of up to 1°, so the image at 14x magnification is rock steady.

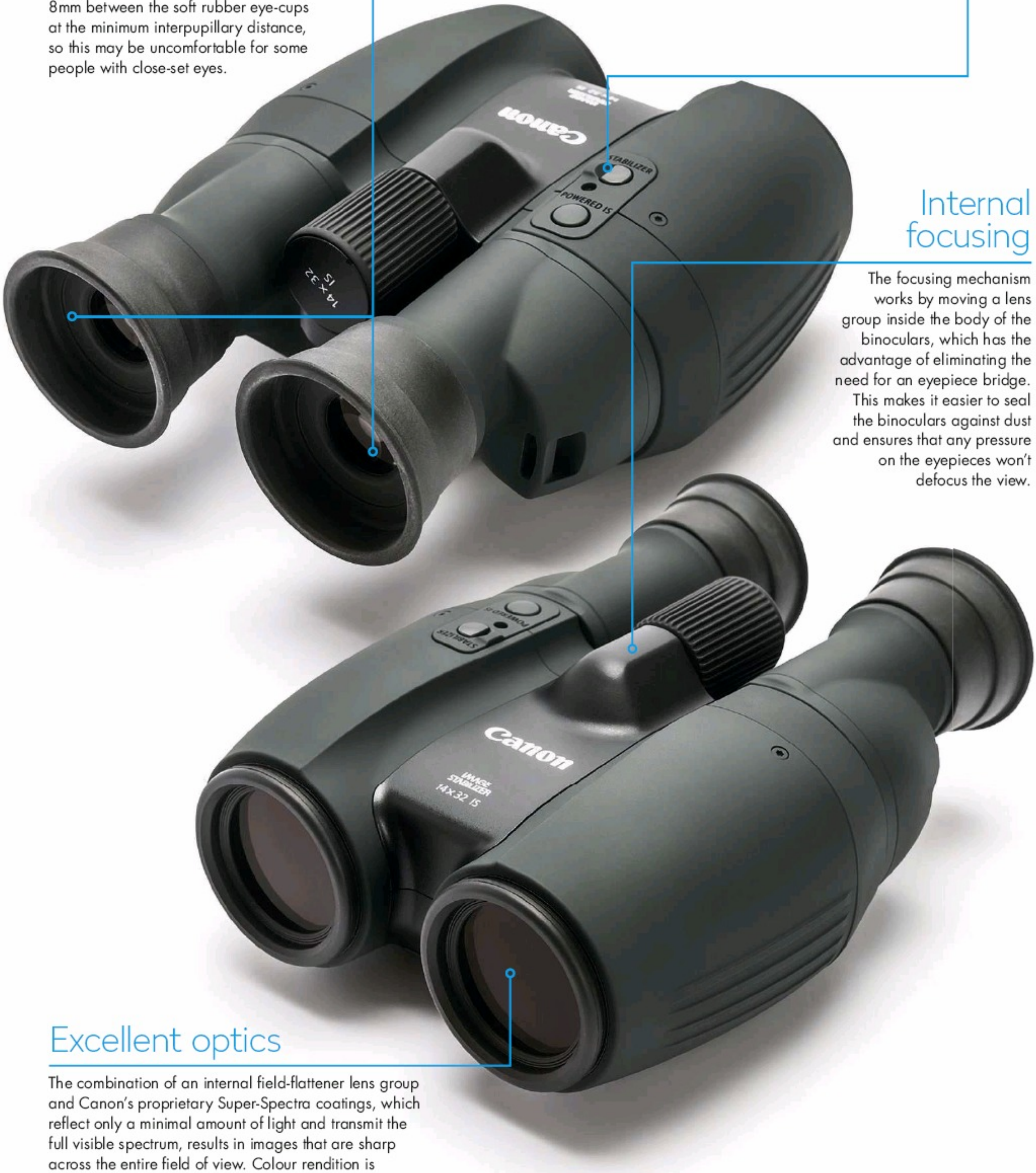
There are also two ways of using each stabiliser mode. If you press and hold a stabiliser button, it will operate only as long as you hold the button down, but if you press and release the button, the stabiliser will stay on for five minutes in normal use; you can press it again to switch it off sooner. To preserve battery life, each of the stabilisers switch off after 10 seconds if the binoculars are facing downwards.

Good IPD range

With the interpupillary distance ranging from 56-78mm, the Canon 14x32 IS will suit a wide variety of faces. The wide eyepiece barrels mean that there's only 8mm between the soft rubber eye-cups at the minimum interpupillary distance, so this may be uncomfortable for some people with close-set eyes.

Tactile button identification

A raised bump on the edge of the concave 'Stabiliser' button enables you to identify it by touch alone, even with gloved hands. This makes it easy to distinguish it from the convex 'Powered IS' button and reduces the likelihood that you'll inadvertently engage the wrong stabilisation mode.



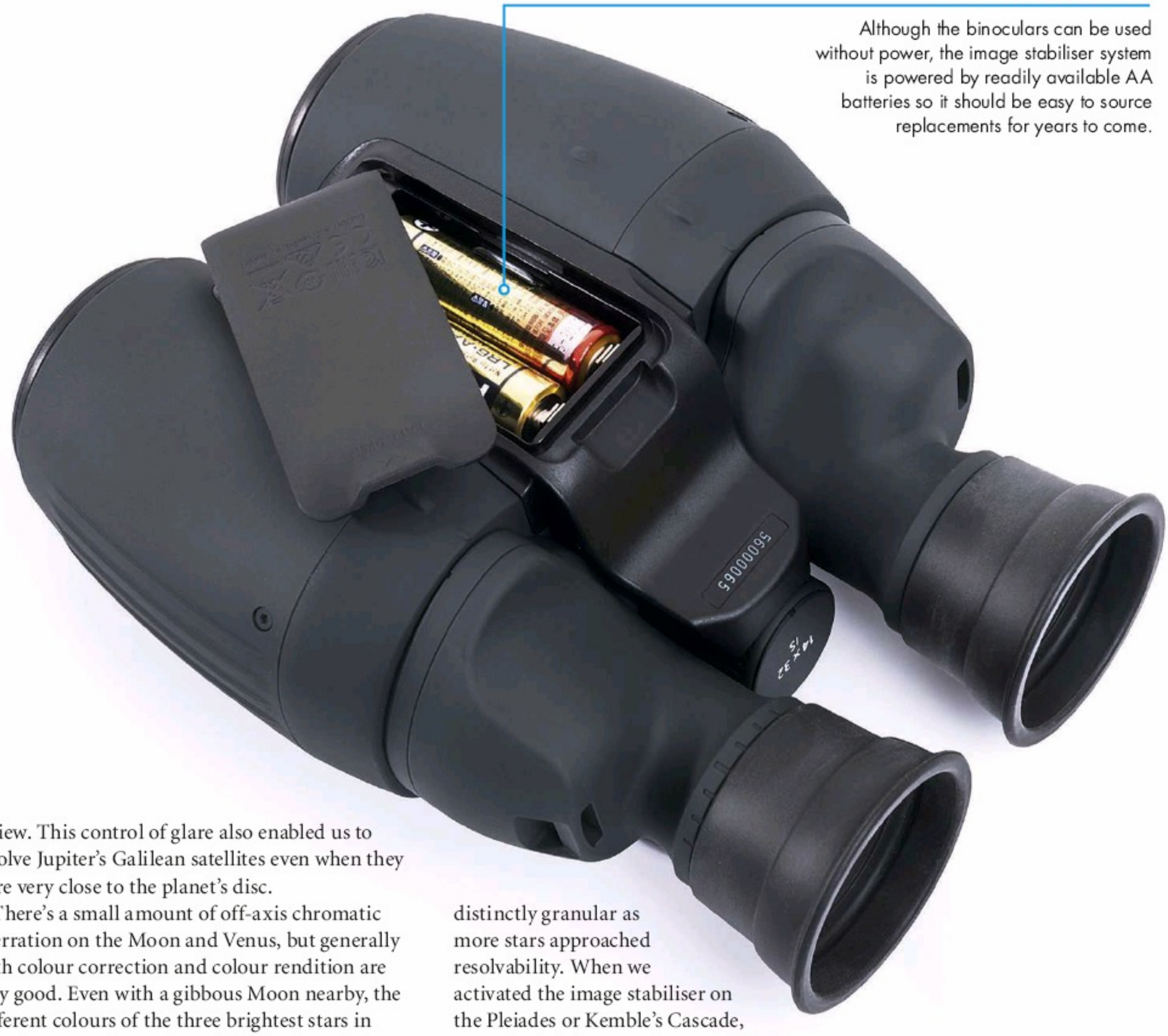
Internal focusing

The focusing mechanism works by moving a lens group inside the body of the binoculars, which has the advantage of eliminating the need for an eyepiece bridge. This makes it easier to seal the binoculars against dust and ensures that any pressure on the eyepieces won't defocus the view.

Excellent optics

The combination of an internal field-flattener lens group and Canon's proprietary Super-Spectra coatings, which reflect only a minimal amount of light and transmit the full visible spectrum, results in images that are sharp across the entire field of view. Colour rendition is faithful with very good contrast.

FIRST **LIGHT**



AA batteries

Although the binoculars can be used without power, the image stabiliser system is powered by readily available AA batteries so it should be easy to source replacements for years to come.

▸ view. This control of glare also enabled us to resolve Jupiter's Galilean satellites even when they were very close to the planet's disc.

There's a small amount of off-axis chromatic aberration on the Moon and Venus, but generally both colour correction and colour rendition are very good. Even with a gibbous Moon nearby, the different colours of the three brightest stars in Orion's Meissa cluster (Lambda (λ), Phi-1 (φ1) and Phi-2 (φ2) Orionis) were distinct.

Stabilising the view

We panned over to the double star Iota (ι) Cancri (mags. +4.0 and +6.0, separation 30 arcseconds) and activated the image stabiliser. The stars immediately split into the two components and they remained separated until they were close to the edge of the field of view, testifying to the efficacy of the field-flattener lens-group.

The laws of optics limit the capability of the 32mm aperture and, although the Orion Nebula (M42) was not particularly bright, it showed some structure when the image stabiliser was activated. Where these binoculars really come into their own, however, is with open clusters and faint asterisms. For example, M35 in Gemini initially appeared as a few stars resolved against a background fuzz but, with the image stabiliser engaged, the fuzz became distinctly granular as more stars approached resolvability. When we activated the image stabiliser on the Pleiades or Kemble's Cascade, not only did the image become still, but more stars became visible as we gained about a quarter of a magnitude in depth.

Incorporating the new image stabiliser system into these binoculars boosts their appeal and usefulness. It helps make the Canon 14x32 IS a great choice for observers looking for multi-purpose small-aperture image-stabilised binoculars to complement their main observing equipment. Ⓢ

Verdict

Build and design	★★★★☆
Ease of use	★★★★★
Features	★★★★★
Image stabilisation	★★★★★
Optics	★★★★½
OVERALL	★★★★★

SKY SAYS…
Now add these:

1. **Lens cleaning kit**
2. **Spare AA batteries**
3. **Sun lounger for viewing comfort**

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www.skyatnightmagazine.com/GPCAM290M

Altair GP-CAM 290M USB3 Mono camera

WORDS: GARY PALMER

Altair's updated camera gets more size, more speed and more cooling

VITAL STATS

- **Price** £329
- **Sensor** Sony Exmor IMX290 CMOS
- **Sensor size** 1/2.8 inch, 6.46mm diagonal
- **Pixels** 1,920x1,080 array, pixel size 2.9 x 2.9um
- **Exposure range** 0.105 milliseconds to 1,000 seconds
- **Bit depth** 8- and 12-bit modes
- **Extras** 1.8m high-speed USB3 cable, 1.5m ST-4 guide cable, 1.25 inch x 20mm nosepiece, CS-Mount adaptor
- **Weight** 80g
- **Supplier** Altair Astro
- **Tel** 01263 731505
- www.altairastro.com

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SKY SAYS...
Altair's GP-CAM 290M USB3 Mono is an excellent all-rounder for a modest price

Altair Astro has completely redesigned its GP-CAM 290M Mono camera. As well as USB3 compatibility this new model also has a larger body, partly to house the new electronics inside but also to accommodate the deeper external fins to help cooling. Also on the rear is an ST4 guide port.

The camera window is clear glass but you can get an IR-coated window as an optional extra. Free software is included with the camera but has to be downloaded from cameras.altairastro.com. Once it's installed and connected, a red LED flashes on the body of the camera to say it's active.

Impressive detail

The 290M USB3 has a wide range of uses from high-speed planetary to deep-sky and electronically assisted astronomy imaging. We initially set the camera up for some solar imaging using a 100mm Lunt telescope and the first thing we noticed is how close objects appear on the screen in relation to the aperture of the telescope. To get the best from the camera a little time and patience is required in order to correctly adjust its settings, including USB speed and bit depth.

The camera didn't drop any frames on the videos we recorded with it running at 125fps and there was some nice fine detail in the solar prominence we captured. Using the camera with SharpCap Pro software (from cameras.altairastro.com) opens up more options for solar and lunar imaging, such as the ability to subtract flat frames while you're recording video and capturing still frames.

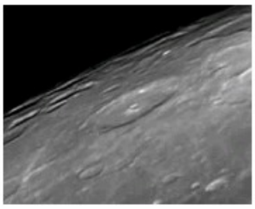
Next we set the camera up for some lunar imaging using a Celestron 11-inch Edge telescope and again, we were very pleased with the detail the camera was able to capture. The view on screen was smooth with no noticeable loss on the display. This makes the camera ideal for live viewing at outreach events and meetings.

Detail in and around the lunar craters was crisp with a nice contrast between the dark and light areas. With the histogram set to 70 in SharpCap ▸

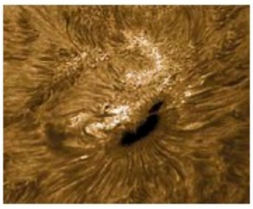
Capable and proficient

The GP-CAM USB3 290M Mono is an excellent all-round camera for a relatively modest price. Having a camera that can image most objects in the night sky and even the daytime (with the appropriate safety filter) is ideal. The camera is suitable for all levels of ability from a beginner to advanced imager, as it has something for everyone. Being able to get close up on targets with modest equipment is always desirable and makes a pleasant change from having to use large-aperture equipment all the time.

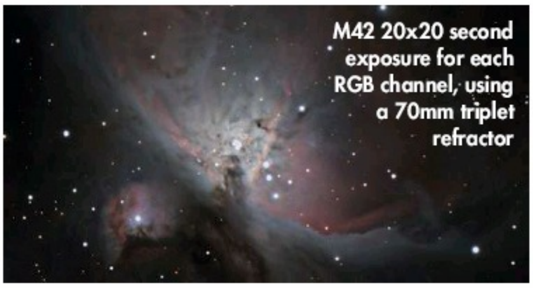
The list of things it can do is long; it has excellent sensitivity, a fast frame rate, gives detailed live-view images, and can image the deep-sky and autoguide to mention just a few of the highlights. Using software such as SharpCap Pro increases the camera's applications even further: options include the polar-alignment and sky background measurement tool to help you get the perfect settings for deep-sky imaging. Excellent build quality on top of all of this means there really isn't anything we didn't like about this camera.



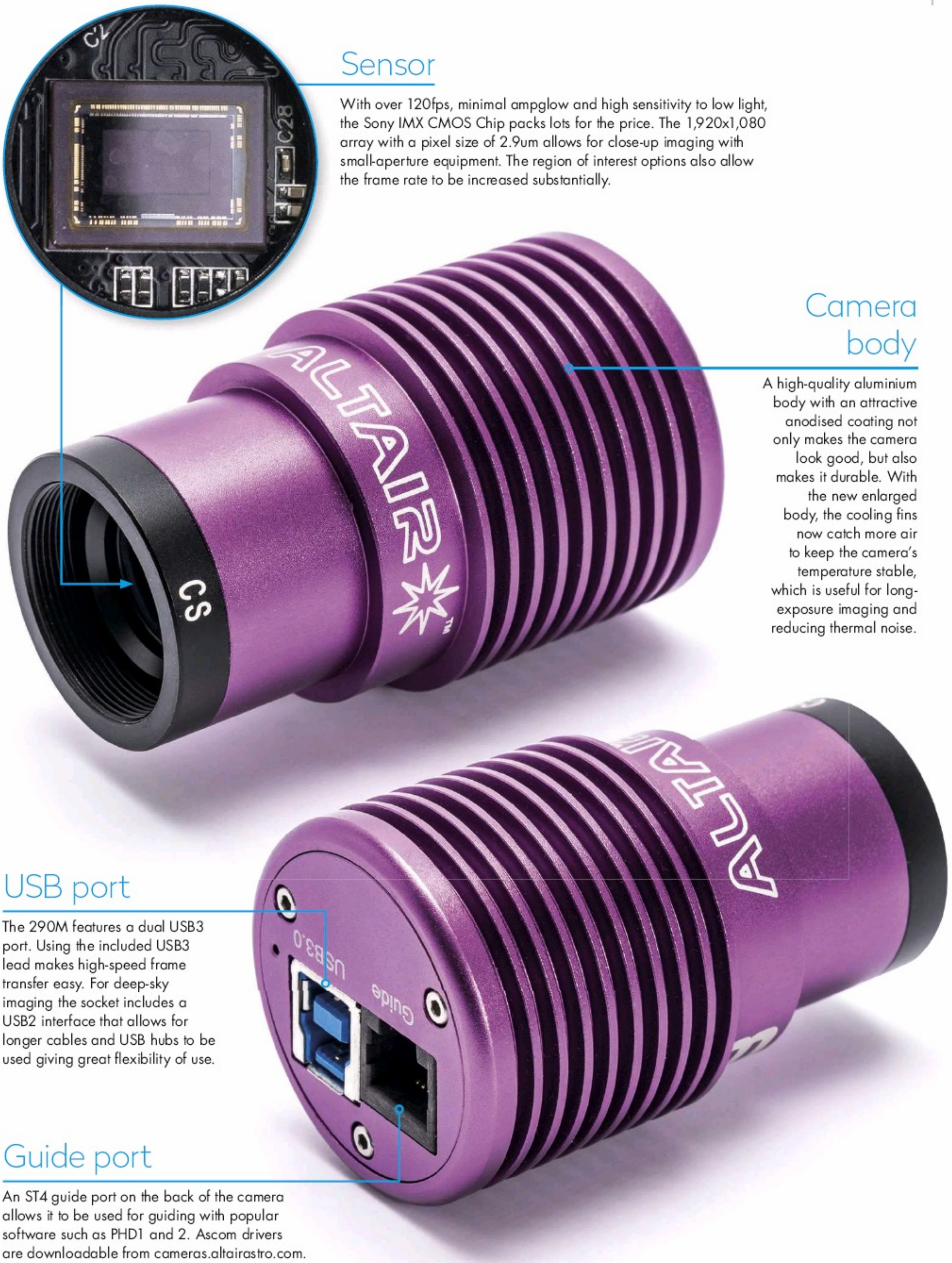
▲ Pythagoras crater captured using a Celestron 11-inch SCT



▲ A sunspot group imaged with a Daystar Quark on a 102mm refractor



M42 20x20 second exposure for each RGB channel, using a 70mm triplet refractor



Sensor

With over 120fps, minimal ampglow and high sensitivity to low light, the Sony IMX CMOS Chip packs lots for the price. The 1,920x1,080 array with a pixel size of 2.9um allows for close-up imaging with small-aperture equipment. The region of interest options also allow the frame rate to be increased substantially.

Camera body

A high-quality aluminium body with an attractive anodised coating not only makes the camera look good, but also makes it durable. With the new enlarged body, the cooling fins now catch more air to keep the camera's temperature stable, which is useful for long-exposure imaging and reducing thermal noise.

USB port

The 290M features a dual USB3 port. Using the included USB3 lead makes high-speed frame transfer easy. For deep-sky imaging the socket includes a USB2 interface that allows for longer cables and USB hubs to be used giving great flexibility of use.

Guide port

An ST4 guide port on the back of the camera allows it to be used for guiding with popular software such as PHD1 and 2. Ascom drivers are downloadable from cameras.altairastro.com. With the camera being so light, it can be attached to lots of different guiding setups.

FIRST **LIGHT**

► Pro every video was consistent in quality when processed. This will make lunar and solar mosaics a breeze to construct. We also tried the camera with a Daystar Quark filter and were rewarded with some stunning shots of groups of sunspots.

Imaging and guiding

Deep-sky imaging is easy but you have to make some changes to the settings for good results. For cameras that aren't actively cooled, such as this one, it's becoming popular to take lots of short exposures instead of a single long exposure. With the 290M USB3 you can choose to run 60 to 100x20-second images and doing so on some equipment would mean that you wouldn't have to use autoguiding software.

Due to poor weather during the test period we didn't get many clear nights to try the camera with narrowband filters, but we did get a short amount of time to image in RGB with the camera set on a filter wheel.

Focusing is easy using a Bahtinov mask, as is adjusting the gain up to brighten the image. For best results the camera needs to be set to high bit mode in whatever software you're using and the gain needs to be set low for image capture. If the gain is set high, images captured will be noisy and hard to calibrate. The 20-second images we produced with it showed no ampglow and the detail in the images captured was very good for such a short exposure time. With the chip being so sensitive it's very easy to capture faint objects.

Using the camera for autoguiding is simple once you've connected it to a mount using the built-in ST4 port and supplied cable. Setting it up using PHD2 guiding software is easy and the camera's sensitivity makes guiding on faint objects, such as comets, simple to do. In short, this is an impressive camera: it's well specced, highly capable and user friendly; all this combined with its price makes it a very tempting piece of kit. Ⓢ

SKY SAYS...
Now add these:
1. Altair Astro Premium CLS-CCD filter
2. Altair 60mm Guide Scope
3. Altair Lightwave 3x Flat Field Tele Extender Barlow

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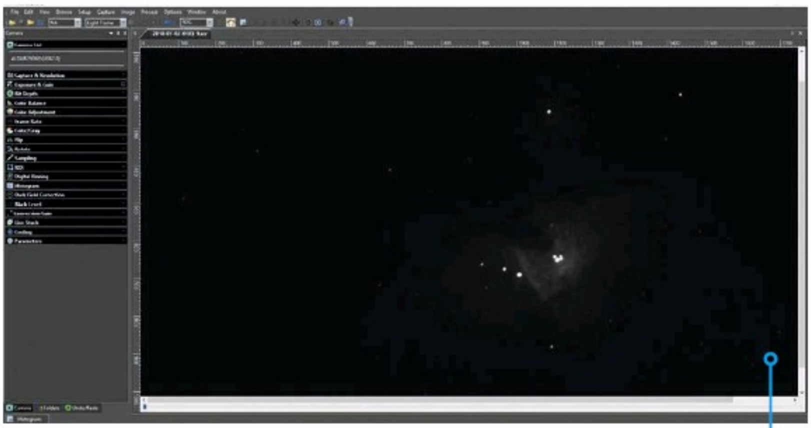


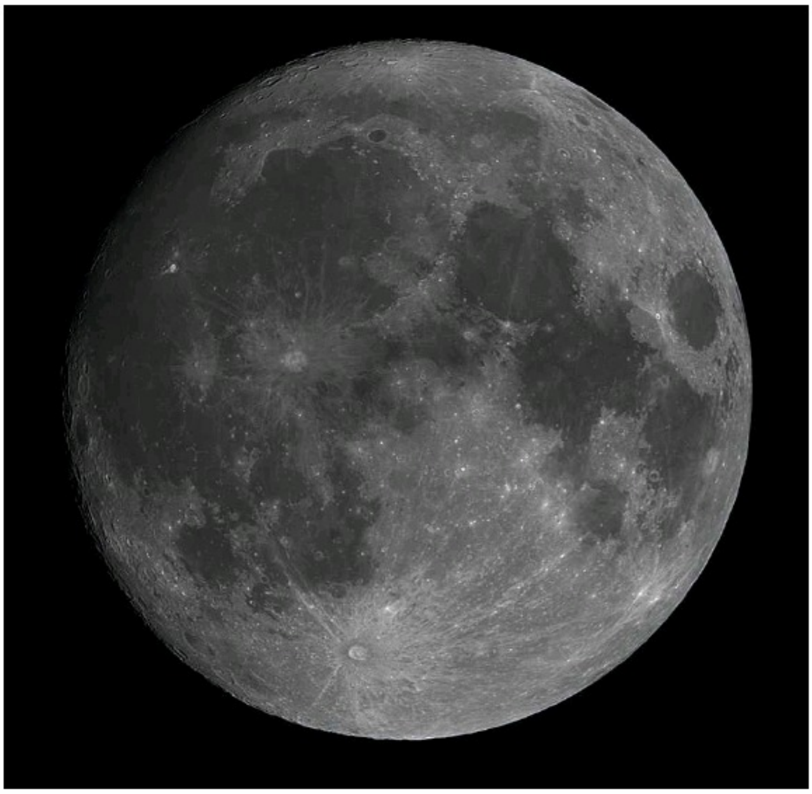
Software

Altair's own AltairCapture software is free to download from cameras.altairastro.com and works well for most applications. Also included with the camera is a free license for SharpCap Pro, a popular choice among imagers with many more options to take advantage of the camera's capabilities.

Verdict

Build and design	★★★★★
Connectivity	★★★★★
Ease of use	★★★★★
Features	★★★★★
Imaging quality	★★★★★
OVERALL	★★★★★

▼ Three panel Moon mosaic, 50 frames stacked from 200 captured for each panel. Imaged using an 80mm triplet refractor using UV/IR cut filter



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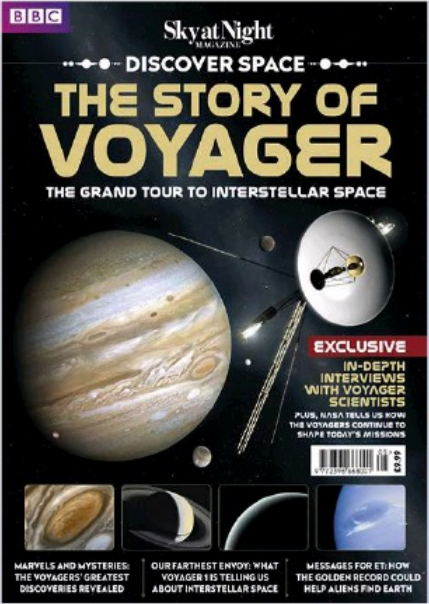
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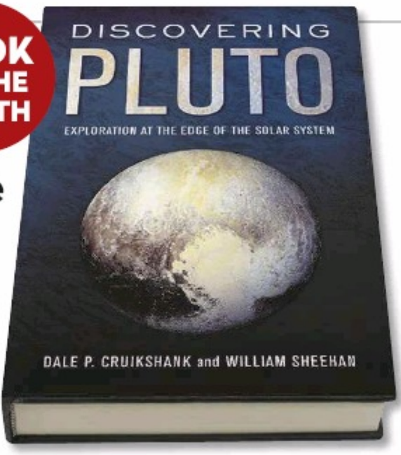
Books

New astronomy and space titles reviewed

RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

BOOK OF THE MONTH


DISCOVERING
PLUTO
EXPLORATION AT THE EDGE OF THE SOLAR SYSTEM
DALE P. CRUIKSHANK and WILLIAM SHEEHAN

Discovering Pluto

Exploration at the Edge of the Solar System

Dale P Cruikshank, William Sheehan
University of Arizona Press
£46.50 ● HB

On 14 July 2015, NASA's New Horizons space probe flew past Pluto, sending home the first detailed images of this distant world. It arrived 88 seconds earlier than expected after a journey of over nine years, during which Pluto lost its status as a planet.

This book tells the inside story of the mission and more. Cruikshank has been a member of the New Horizons team since the mission was first planned and Sheehan is a leading astronomical historian.

The story begins in the 18th century when the known Solar System ended at Saturn. The discovery of ice giant Uranus by Sir William Herschel in 1781 changed all that. Subsequent observations showed Uranus's orbit was being perturbed and so the search began for a planet beyond it.

That French mathematician Urbain Le Verrier beat Englishman John Couch Adams to locating Neptune is well known, but this detective story is told in fascinating detail; a quality that runs throughout the book's telling of historic events.

Brought to life too is the colourful career of Percival Lowell, whose obsession with Mars – and deep pockets – provided the observatory and equipment that made Pluto's discovery by former farm boy Clyde Tombaugh possible in 1930.

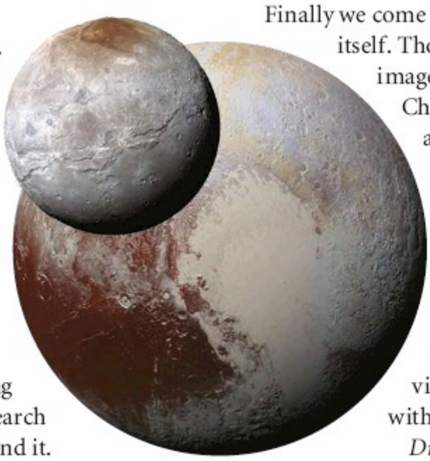
Readers are taken through the advances made in our knowledge of the outer Solar System during the Space Age, including the discovery of methane ice on Pluto, its biggest moon Charon in 1978 and then the presence of an atmosphere in 1988.

Finally we come to New Horizons itself. Those jaw-dropping images of Pluto and Charon, quite unlike anything seen before, are described clearly yet in a non-technical way. But the mission is not yet over, as the spacecraft is now making its way to visit a new target within the Kuiper Belt.

Discovering Pluto is a beautiful book that will delight anyone interested in the Solar System. It skilfully blends historical tales of discovery with the excitement of modern science. And it shows that the dwarf planet Pluto is no less intriguing, however you label it.

★★★★★

PAUL SUTHERLAND *is a space writer and journalist*


Pluto, now designated a dwarf planet, and the biggest of its moons, Charon

NASA/JHUAPL/SWRI X 2

TWO MINUTES WITH

Dale P Cruikshank

How did our relationship with Pluto begin?
In 1915, American astronomer and mathematician Percival Lowell predicted a planet beyond Neptune that was causing the motion of Uranus to be irregular, but couldn't find it before his death in 1916. The search continued and in 1930 Clyde Tombaugh found Pluto, but it wasn't quite where Lowell predicted and we later found that it is too small to have affected Uranus's motion.

The debate continues: is Pluto a planet?
As defined by the International Astronomical Union, Pluto is a dwarf planet. Pluto is smaller than Earth's Moon, but has five moons of its own, active geological processes (moving glaciers) and an atmosphere. In the eyes of many, these and other physical characteristics make Pluto a fully fledged planet.

What were the major challenges and discoveries of New Horizons?
The challenges were getting the spacecraft funded, built and launched, and keeping it working for the 9.5-year trip. Once there, we discovered active geological and atmospheric processes, exposed water ice on the surface and a hazy atmosphere, among other things.

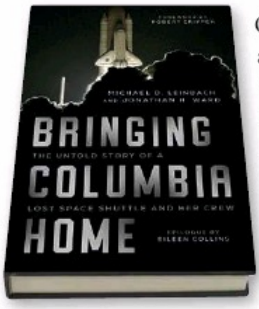
How will the mission end?
New Horizons is on its way to the small Kuiper Belt object 2014 MU69, with a flyby planned for 1 January 2019. The spacecraft will then continue into deep space, eventually leaving the Solar System and running out of power.

DALE P CRUIKSHANK *is an astronomer and a co-investigator on New Horizons*

Bringing Columbia Home

The Untold Story of a Lost Space Shuttle and Her Crew

Michael D Leinbach, Jonathan Ward
Arcade Publishing
£18.99 ● HB


BRINGING COLUMBIA HOME
THE UNTOLD STORY OF A LOST SPACE SHUTTLE AND HER CREW
MICHAEL D. LEINBACH AND JONATHAN H. WARD

On 1 February 2003, a long and painful recovery got underway to bring seven fallen astronauts and NASA's flagship Space Shuttle home. Columbia was destroyed during re-entry and the next few months would remind NASA that space travel is a harsh and unforgiving business.

Written by NASA launch director Mike Leinbach and space historian Jonathan Ward, *Bringing Columbia Home* tells the story of STS-107, from its warm-hearted crew to its catastrophic return to Earth and the efforts of 25,000 volunteers to find the ship's remains.

The memory of Columbia's sister Challenger, lost 17 years earlier, haunts this book. Leinbach and Ward outline similar schedule pressures, bureaucratic obstacles and engineers whose concerns were disregarded by senior managers.

The authors list missed warnings of impending doom. Photos of the Shuttle's external tank, the root cause of the disaster, were never analysed; images of the mortally scarred Columbia in space were never requested; and long-range tracking cameras were either out of focus or not functional. 100 successful missions had convinced managers of the Shuttle's invincibility.

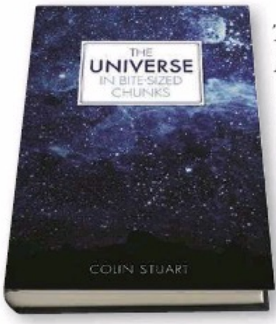
Bringing Columbia Home reminds us of the people who died as a result of the Columbia disaster. And we are reminded of Columbia herself, "the beloved black sheep of the fleet". Telling the story of a mission without mentioning the spacecraft, one NASA quality inspector reflected, is like telling the story of *Star Trek* without mentioning the Enterprise.

★★★★★

BEN EVANS *is a science and astronomy writer*

The Universe in Bite-sized Chunks

Colin Stuart
Michael O'Mara
£9.99 ● HB



The Universe in Bite-sized Chunks really is just that; a whistle-stop tour of our spectacular Universe in small, easy-to-manage, fun-to-read pieces. Without complicated jargon or intimidating equations, Colin Stuart takes the reader on a journey from our Solar System to the farthest corner of the Universe, exploring all of the sights along the way.

Starting with a brief history of time-keeping on Earth, we learn about the great astronomers of the past and how they contributed to our heliocentric, Copernican view of the Solar System. If the science of stars, galaxies and everything in-between is the main course, then cosmology is for dessert. To conclude, we're treated to a fantastic overview of current theories about how the Universe began and its ultimate fate "in approximately 22 billion years".

From mini-biographies to mission profiles, from Albert Einstein to the Cassini probe, this book is full of interesting snippets highlighted in boxes throughout. For example, did you know the Juno spacecraft, currently in orbit around Jupiter, carries three Lego figures on board? With useful headings such as 'The Drake Equation' and 'The Asteroid Belt', the book is also well structured, making it very easy to navigate.

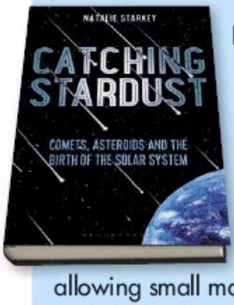
If you're already quite familiar with many of the Universe's wonders, though, this book might not be for you. It introduces a wide variety of topics in astronomy but lacks depth. If you're new to the subject, however, or are trying to spark the astronomy bug in someone else, then this volume is an excellent place to begin your adventure.

★★★★☆

AMBER HORNSBY *is a postgraduate researcher at Cardiff University*

Catching Stardust: Comets, Asteroids and the Birth of the Solar System

Natalie Starkey
Bloomsbury Sigma
£14.99 ● HB



It seems we may owe a lot to comets and asteroids – our very existence perhaps. Not only is it likely that one of these killed off the dinosaurs, allowing small mammals to prosper and ultimately evolve into human beings, but they may also have provided Earth with the necessary raw materials for life to begin. Scarily, if one were to impact today, it might also initiate our demise.

With the intention of promoting the study of comets and asteroids to further understand their role in the development of life, to aid on-going efforts to avoid disaster if one were on a collision course with Earth and generally to learn more about how our Solar System evolved, this book provides a great introduction to these small celestial bodies. It summarises what we know about them, describes current efforts to locate and monitor them and even discusses the feasibility of mining them.

What stands out about this book, however, are the chapters describing two recent missions to comets: Stardust and Rosetta. Natalie Starkey's experience working on these missions has enabled her to provide clear and insightful descriptions of them and their results, with a few wonderfully random details thrown in.

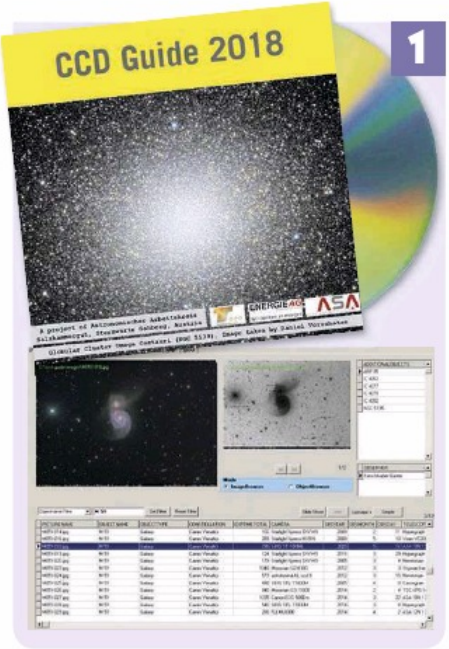
The book could use a few more images but the well-written narrative makes *Catching Stardust* an enjoyable read that effectively argues the case for more missions to study comets and asteroids.

★★★★★

DR PENNY WOZNIAKIEWICZ *is a lecturer in space science at the University of Kent*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories



1 CCD Guide 2018

Price €29 (£25.60*) • **Supplier** Astro Systeme Austria www.ccdguide.com

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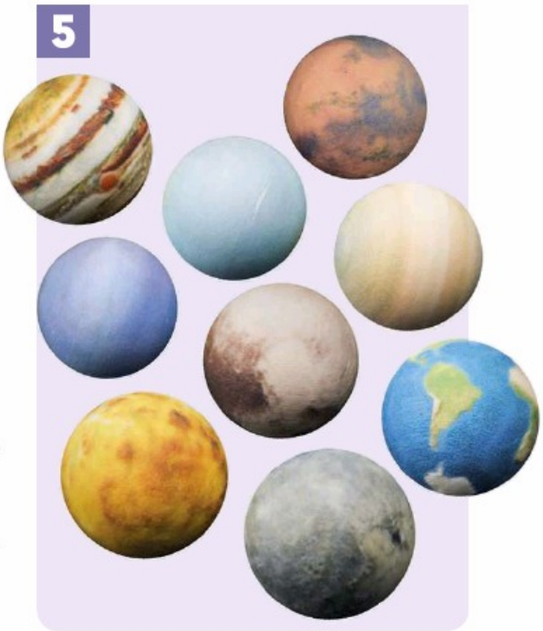

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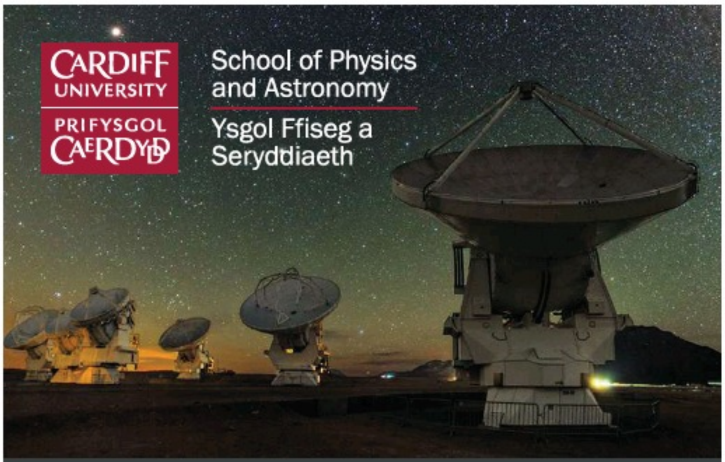

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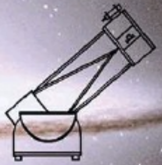

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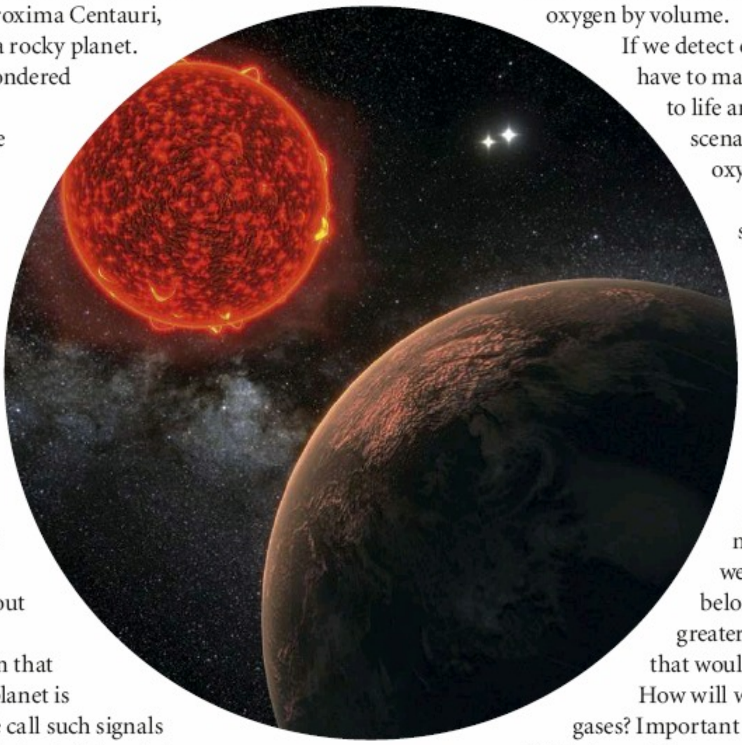
WHAT I REALLY WANT TO KNOW IS...

How can we detect life on other planets?

Professor Sara Seager is searching for gases in alien atmospheres that could tell us if they are inhabited

INTERVIEWED BY PAUL SUTHERLAND



Proxima Centauri B orbits in the habitable zone around the nearest star to our Sun

RICARDO RAMIREZ AND JAMES JENKINS (DEPARTMENT OF ASTRONOMY/UNIVERSIDAD DE CHILE)

Planets are extremely common. We know of thousands and almost every star seems to have some kind of planetary system. Our nearest star, Proxima Centauri, has what might be a rocky planet. For years people wondered about worlds beyond our Solar System. The fact that there's one right next door is amazing.

My research led to the first detection of an atmosphere on an exoplanet. I had described how one might detect the atmosphere of a planet if it passed in front of its star. Starlight shines through the atmosphere and the atmospheric features of the planet get imprinted on the star. By subtracting the light from a star when a planet is not transiting from that when it is, you're left with information about the planet's atmosphere.

I'm interested in the signals in that data which might tell us if the planet is habitable or even inhabited. We call such signals biosignature gases. The subject is hotly debated, but everyone pretty much agrees that water vapour on a small rocky planet is an indicator of habitability because all life as we know it needs liquid water.

A massive enough planet will have water vapour in its atmosphere without there being oceans. We've seen that in giant planets already. Earth has oceans because the water evaporates, rises to form clouds and then it rains. But on some planets hotter than Earth that water will evaporate and keep rising into the atmosphere. On other planets hotter than Earth, that water vapour rises so high in the atmosphere that, instead of turning to rain, the hydrogen is stripped out and escapes into space. A planet needs to be small and rocky like Earth to have oceans.

The puzzle of oxygen

Finding certain gases in an atmosphere could also indicate whether a planet has life. A simple lifeform, cyanobacteria, transformed Earth's atmosphere billions of years ago when these organisms figured out how to harness energy from the Sun. But in doing so they created oxygen as a byproduct, which was poisonous to everything around them. They nearly killed their world but totally reengineered our atmosphere, so that it now has 20 per cent oxygen by volume.

If we detect oxygen on another planet we'll have to make sure that it can be attributed to life and not another environmental scenario. We can't simply find oxygen and be excited about it.

On Earth, microbes create all sorts of chemicals. You can walk into a swamp and it smells terrible, or into a pine forest and it smells beautiful. Both of those scents are entirely due to the gases produced by life.

Astronomers will be looking for oxygen first and then methane, nitrous oxide and maybe hydrogen sulphide. If we recognise a gas that doesn't belong, or seems to be there in greater quantities than expected, that would be interesting.

How will we search for biosignature gases? Important tools will be NASA's James Webb Space Telescope, plus the new generation of ground-based telescopes such as the Giant Magellan Telescope, the European Extremely Large Telescope and the Thirty Meter Telescope. They'll study M-dwarf stars in different wavelengths and with different techniques. We might like to study Sun-like stars but their brightness would overpower the faint signals we're searching for.

But to find a twin for Earth, we need to go into space and block out the starlight so that we can see the planet directly. Even the new, ground-based telescopes can't block out starlight to the one part in 10 billion needed to spot another Earth. My favourite space-based mission concept is the Starshade, a giant specially shaped screen that blocks out starlight so a distant telescope will only detect the planet's light.

My personal ambition is to find another Earth. But when might we get an answer to whether there is life out there? It really could be at any time. Once the James Webb launches, and if planets and life are extremely common, then we could get incredibly lucky. But if life is not there around M-dwarf stars, we will have to wait a lot longer. Ⓢ

ABOUT SARA SEAGER
Professor Sara Seager is an astrophysicist and planetary scientist at the Massachusetts Institute of Technology where she has made it her goal to discover Earth-like worlds.

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THE SOUTHERN HEMISPHERE IN MARCH

With Glenn Dawes

WHEN TO USE THIS CHART

1 MAR AT 00:00 UT
15 MAR AT 23:00 UT
31 MAR AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

MARCH HIGHLIGHTS

The Gamma Normids, one of the few showers exclusive to the southern hemisphere, is visible from 25 February to 28 March. The radiant's position is about halfway between the bend in Scorpius's tail and Alpha Centauri. Its maximum occurs on 14 March. The shower will have gained a reasonable altitude by midnight, leaving around three hours of dark morning skies to observe. Although historically not a strong display, there are occasional bright yellow members known to leave trains.

STARS AND CONSTELLATIONS

One of the original constellations Argo Navis, the Ship Argo, is today broken up into Carina, Puppis and Vela. But the Bayer naming system still reflects the ancient ship constellation. Among these three modern constellations there is only one star called 'Alpha', 'Beta', 'Gamma' and so on. The alpha star resides in Carina, the second brightest in the sky, Canopus. It's not only people from Down Under that appreciate its prominence – many robotic space probes use it as a key navigation star.

THE PLANETS

Venus and Mercury appear in the evening twilight moving together for the first half of March. Although Venus is at mag. –3.9, it remains difficult to see in the bright sky. Jupiter is rising in the early evening (21:30 EST mid-month) and is well placed in the morning sky, transiting just before dawn. Mars arrives just before midnight, followed by Saturn around 30 minutes later. Mars and Saturn begin the month with a separation of 17° but by the month's end it's less than 2°.

DEEP-SKY OBJECTS

North of Vela lies the constellation of Pyxis, the Mariner's Compass. Zeta Pyxidis is an isolated, faint (mag. +4.9), naked-eye star. Within the same low-power eyepiece field is the mag. +8.4 open star cluster NGC 2627 (RA 8h 37.2m, dec. –29°57'). This cluster of around 40 10th- to 12th-magnitude stars is well spread, giving a rectangular appearance of around 5x8 arcminutes.

A jump of 7° due north finds another isolated 5th-magnitude star, HD 73752. Moving 1.4° west brings you to the impressive, mag. +10.2 galaxy NGC 2613 (RA 8h 33.4m, dec. –22° 58'; pictured). This near edge-on spiral presents a 1x5-arcminute halo in a nice star field, including a bright (mag. +11.1) star on the northwest tip. There is a prominent, bright central core with a faint stellar nucleus.

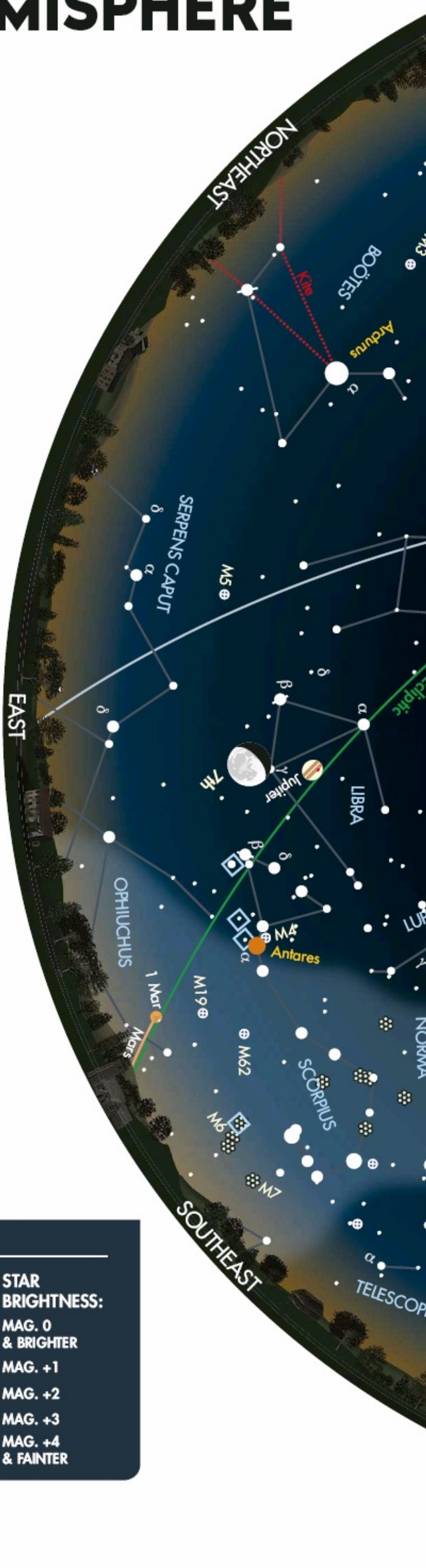


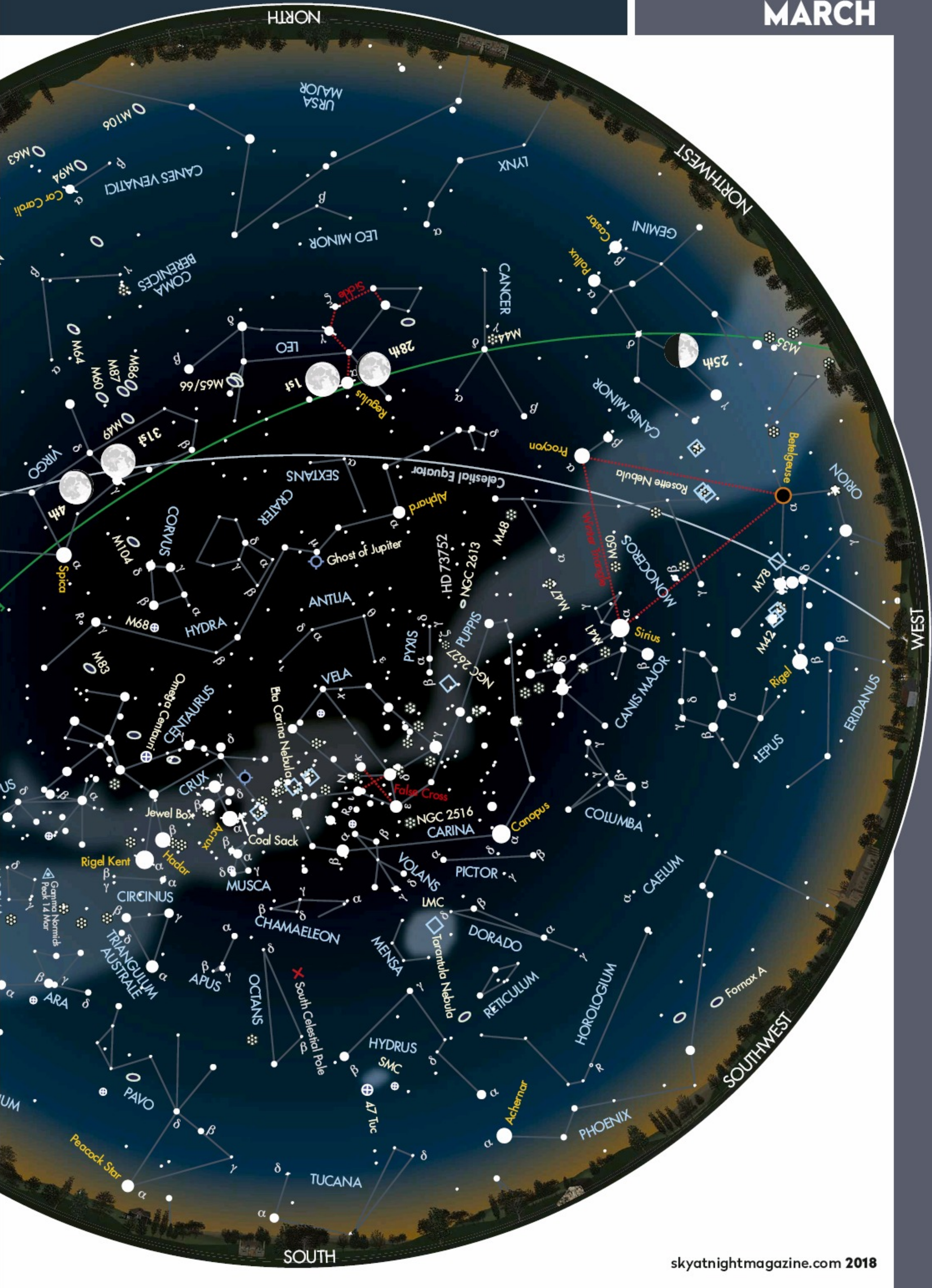
CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:

- ● MAG. 0 & BRIGHTER
- ● MAG. +1
- • MAG. +2
- • MAG. +3
- · MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: DANIEL VERSCHATSE/CCDGUIDE.COM


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
LYNX
CANES VENATICI
Cor Caroli
M94
M63
M106
LEO MINOR
GEMINI
Castor
Pollux
COMA BERENICES
CANCER
M44
Sickle
LEO
28th
1st
Regulus
M65/66
M64
M60
M87
M86
M49
31st
VIRGO
4th
Spica
25th
M35
CANIS MINOR
Procyon
Betelgeuse
ORION
Rosette Nebula
Celestial Equator
SEXTANS
CRATER
Alphard
CORVUS
M104
Ghost of Jupiter
M48
HD 73752
NGC 2613
M50
MONOCEROS
Winter Triangle
M78
M42
ANTLIA
HYDRA
M68
M83
PYXIS
PUPPIS
M47
M41
Sirius
Rigel
CANIS MAJOR
ERIDANUS
LEPUS
NGC 2627
VELA
Eta Carina Nebula
Omega Centauri
CENTAURUS
CRUX
False Cross
NGC 2516
CARINA
Canopus
COLUMBA
Jewel Box
Acrux
Coal Sack
Hadar
Rigel Kent
MUSCA
CIRCINUS
Gamma Normids
Peak 14 Mar
VOLANS
PICTOR
LMC
CAELUM
CHAMAELEON
DORADO
MENSA
Tarantula Nebula
TRIANGULUM AUSTRALE
APUS
ARA
OCTANS
South Celestial Pole
RETICULUM
HOROLOGIUM
Fornax A
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47 Tuc
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